

# **GRAND RIVER BASIN WATER MANAGEMENT STUDY**

## **TECHNICAL REPORT SERIES**



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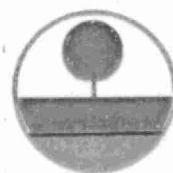
### **CONTINUOUS MONITORING OF DISSOLVED OXYGEN**

**TECHNICAL REPORT Nº 11**



Ontario

**GRAND RIVER IMPLEMENTATION  
COMMITTEE**



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GRAND RIVER BASIN WATER MANAGEMENT STUDY

TECHNICAL REPORT SERIES

REPORT # 11

CONTINUOUS MONITORING OF DISSOLVED OXYGEN

PREPARED FOR THE GRAND RIVER IMPLEMENTATION COMMITTEE BY:

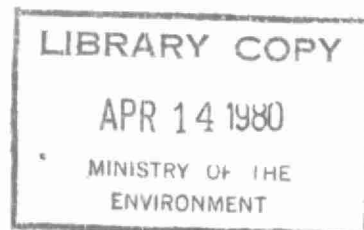
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January, 1980  
Water Resources Branch  
Ontario Ministry of the Environment  
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## FOREWORD

The report, 'Continuous Monitoring of Dissolved Oxygen' is one of a series of technical documents prepared for the Grand River Basin Water Management Study. The project described herein was undertaken through the Grand River Study Team at the request of the Grand River Implementation Committee.

The material contained in these reports is primarily technical support information and, in itself, does not necessarily constitute policy or management practices. Interpretation and evaluation of the data and findings, in most cases, cannot be based solely on this one report but should be analyzed in light of other reports produced within the comprehensive framework of the overall study. Questions with respect to the contents of this report should be directed to the Co-ordinator of the Grand River Study, c/o J.G. Ralston, Water Resources Branch, Ministry of the Environment, 135 St. Clair Avenue West, Toronto.

## CREDITS AND ACKNOWLEDGEMENTS

Mr. R. C. Ostry of the Hydrology and Monitoring Section, is the Project Leader in charge of the installation, operation and maintenance of the network, including the processing of EIL records.

Dr. T. P. Halappa Gowda of the Water Modelling Section is the Project Leader in charge of the processing and technical analysis of the continuous monitoring records.

The writers wish to express their appreciation to J. Ralston and T. Tseng of the Planning and Co-ordination Section for suggesting the inclusion of sections on data accuracy and analysis of dissolved oxygen data in light of the new provincial water quality objectives. Thanks are also due to D. N. Jeffs, F. C. Fleischer, D. G. Weatherbe and R. Weiler for their constructive criticisms in reviewing the report. The assistance of K. Wan and K. Willson in developing additional computer programs is also gratefully acknowledged.

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Reference to equipment, brand names or suppliers in this publication is not to be interpreted as an endorsement of that product or supplier by the authors or the Ministry of the Environment.

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## ABSTRACT

At the time of initiation of the Grand River Basin Water Management Study in 1975, a network of seven continuous monitoring stations was established to monitor important water quality parameters in the central megalopolis area of the basin at the following locations: on the Grand River at Bridgeport, Woolners Flats, Blair and Glen Morris, and on the Speed River at Canadian Gypsum near Guelph, Glen Christie and Preston. Dissolved oxygen and temperature are monitored continuously at five stations using EIL (Electronic Instruments Ltd.) instrument systems. At two other locations, NERA (New England Research Associates Inc.) instrument systems record dissolved oxygen, temperature, conductivity, pH and redox potential at half-hourly intervals.

The procedures involved in the processing and storage of the water quality records of these two instrument systems are outlined in this report. Results of statistical and probabilistic analysis of the dissolved oxygen data collected during the period May 1975 - December 1978 are also presented. The results indicate that minimum daily dissolved oxygen levels were generally lower than the criteria levels of 4 to 5 mg/L during the months of June and July at all stations, with the exception of the Speed River at Glen Christie where the minimum daily concentrations were less than 4 mg/L frequently during the period May - November.

The percentage of days in each month in which the minimum recorded dissolved oxygen levels were in violation was computed for each station in two ways:

- (i) as per the former provincial criteria for warm water biota (in which minimum concentrations are specified); and
- (ii) according to the present provincial objectives for warm water biota wherein the DO saturation levels (and concentrations) are specified as a function of temperature.

A comparison of the above analyses indicates that violations as per the present provincial objectives are generally less frequent than those of the former criteria, except in the case of the Speed River at Glen Christie where the opposite is true. It is also evident from this analysis that longer periods of DO criteria violation occur under the former criteria, and that some periods of record are in violation of the old criteria, but not the new objectives.

## 1. INTRODUCTION

### 1.1 GENERAL

At the time of initiation of the Grand River Basin Water Management Study in 1975, a network of seven continuous monitoring stations was established at strategic locations on the Grand and Speed rivers in the central megalopolis area of the river basin. These were instrumented to monitor several parameters considered necessary for the diagnosis of water quality problems. Two more stations were established during 1978 and 1979 in the lower megalopolis area of Brantford, thus increasing the total number of continuous monitoring stations to nine.

Technical Report No.11 describes: (i) the selection, installation and maintenance of the monitoring systems; (ii) processing and storage of data; and (iii) statistical and probabilistic analysis of the data collected during the period 1975-1978 at the seven stations established during 1975.

### 1.2 PURPOSES OF CONTINUOUS MONITORING OF WATER QUALITY

A major objective of the collection of continuous data on dissolved oxygen (DO), temperature and other water quality parameters in the Grand River basin is to provide data required in the development and verification of a continuous simulation water quality model. This model when complete, will be used to evaluate various water management alternatives in the megalopolis area of the Grand River basin. Thus, the continuous monitoring network data will aid in the long range planning and management of water quality in the basin.

The continuous monitoring data are also useful in determining the frequency of violation of the provincial water quality criteria during selected seasons (e.g., monthly intervals).

These results should be of particular interest to those involved in planning and surveillance of water quality, as well as to the general public.

The data can be used to identify water quality impacts attributable to an event-oriented source such as pollution due to storm water runoff, as well as to detect long-term trends in water quality.

A potential application of continuous monitoring is the incorporation into a real-time control system, for management of water quality through proper scheduling of reservoir releases, water takings for water supply and control of treatment plant operations. The application of continuous water quality monitoring in river management is presented by Birch, et al (1) and Davies (2).

At the time of the writing of this report, data analysis has been oriented to identifying water quality criteria violations and to supporting work on the Grand River continuous simulation water quality model.

### 1.3 SELECTION OF SITES

The monitoring network consists of nine stations shown on the basin map in Figure 1. The stations were selected based on the following rationale:

Stations at the Canadian Gypsum Plant near Guelph on the Speed River, and at the Bridgeport Road near Waterloo on the Grand River were required to record water quality at the upstream boundaries of the megalopolis area. The DO levels recorded at these sites generally reflect the effects of rural runoff and wastewater effluents in the upper reaches of the Grand and Speed rivers.

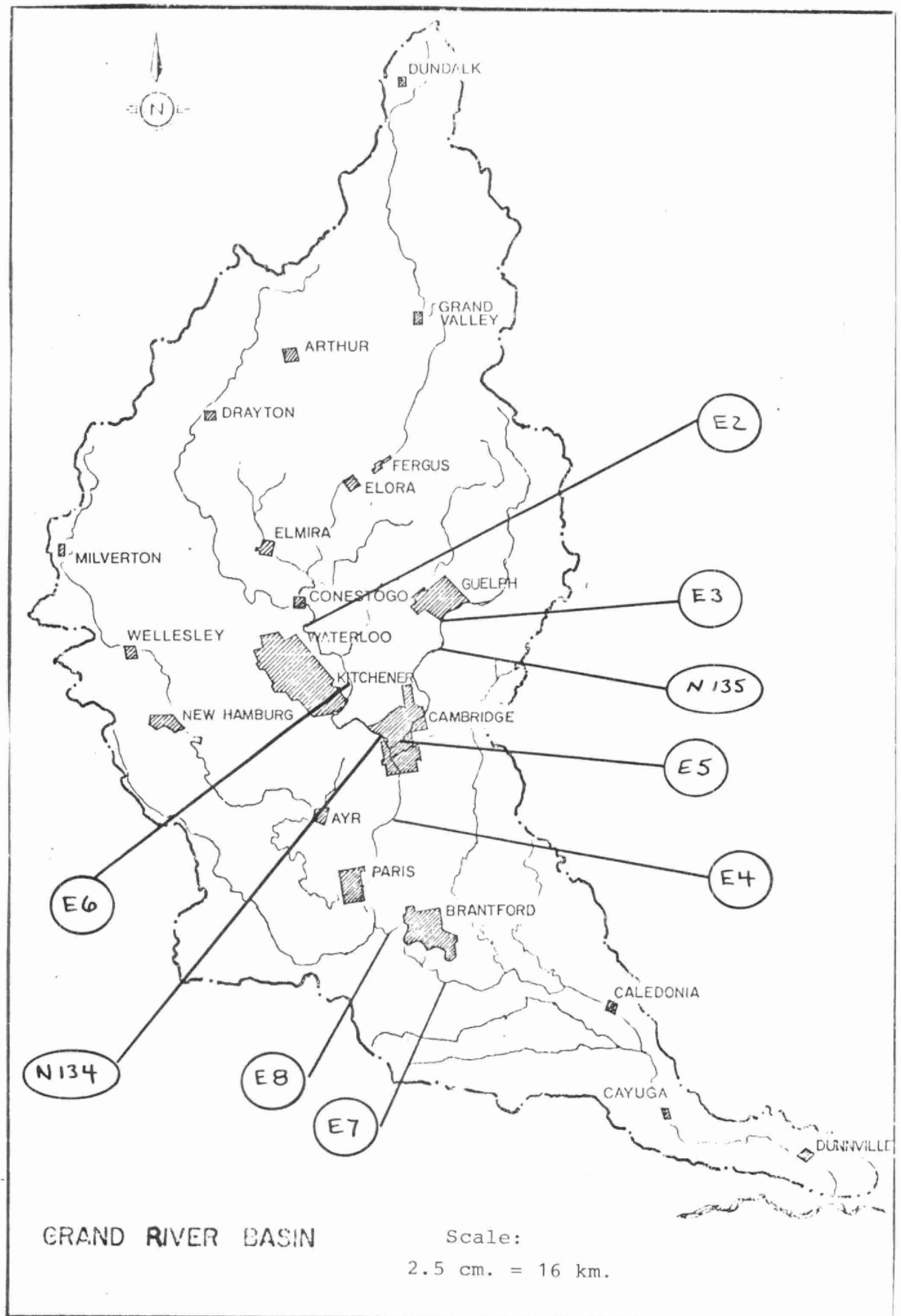


Figure 1 - CONTINUOUS MONITORING NETWORK  
GRAND RIVER BASIN

The siting of the remaining seven stations, located downstream of major effluent discharge points, was based on estimates of the downstream distance required for the effluent to have mixed completely in the entire cross section of the river. The distance required for complete mixing of effluent and streamwater is usually known as the "mixing zone length". The mixing zone lengths were estimated from the geometry, streamflow and other pertinent hydraulic characteristics of the stream channels. Because of the shallow nature of the streams, the distance required for complete transverse mixing generally assures complete vertical mixing. (As a rule-of-thumb, the distance required for complete mixing in the vertical direction is about 100 times the depth; whereas, complete lateral mixing is likely to occur in a distance of about 100 times the width). When the mixing zone lengths were established, final site selection was based on practical considerations such as public right-of-way and uniformity of cross-section in a reasonably straight reach.

The type of instrument system installed at each location is shown in Table 1. The relocation of Station E2, indicated in Table 1 was necessitated by operational problems. A brief description of the systems is presented in the next chapter.

#### 1.4 PERIODS OF RECORD AND DATA ANALYSIS

Since the establishment of the continuous monitoring network, field installations and operational procedures have improved to the extent that the sites can now be kept in operation on a year-round basis, except during extreme spring runoff conditions. Figure 2 shows the extent of the data recorded by station and month since the installation, and indicates that portion of the data which has been analyzed and presented in this report. As stated before, the analysis presented in this report is confined to the data collected during 1975-1978, at the seven stations operational since 1975.

TABLE 1. DETAILS OF CONTINUOUS MONITORING NETWORK

Location of Station	Station Number	Instrument System	Distance above mouth of Grand River (km)	Remarks
Grand River at Bridgeport	E2	EIL*	176.8	Installed in May, 1975 on the east bank about 0.5 km upstream of bridge; relocated in April 1977 on the west bank about 1 km upstream of the bridge.
Grand River at Woolner Flats	E6	EIL	166.4	Installed in July 1975
Grand River at Blair	N134	NERA**	150.0	Installed in September 1975
Speed River at Canadian Gypsum Plant	E3	EIL	166.0	Installed in June 1975 with housing on the Canadian Gypsum property; housing relocated on the Guelph WPCP property during Nov. 1978.
Speed River at Glen Christie	N135	NERA	163.5	Installed in September 1975
Speed River at Preston	E5	EIL	149.4	Installed in May 1975
Grand River at Glen Morris	E4	EIL	132.8	Installed in June 1975
Grand River Upstream of Wilkes Dam	E8	EIL	108.8	Installed in May 1979
Grand River at Newport Bridge	E7	EIL	78.4	Installed in July 1978

\* EIL records DO and temperature

\*\* NERA records DO, temperature, pH, conductivity and oxidation - reduction potential.

○ DATA COLLECTED - NOT ANALYZED.      □ PART MONTH DATA, ANALYZED.      ■ >20 DAYS DATA, ANALYZED.

Figure 2 - PERIODS OF RECORD AND ANALYSIS OF DATA

## 2. DESCRIPTION OF MONITORING SYSTEMS

### 2.1 INSTRUMENT SYSTEMS

Two types of instrument systems were installed at the nine stations of the continuous monitoring network in the Grand River Basin. At seven locations, the monitoring system consists of an EIL model 15A meter (manufactured by Electronic Instruments Limited) in combination with a Rustrak model-388 recorder, which records dissolved oxygen (DO) and water temperature continuously on a double-strip chart. At two locations, NERA model-4 monitors (manufactured by the New England Research Associates Inc.), were installed. The NERA system records dissolved oxygen (DO), water temperature, conductivity, pH and oxidation-reduction redox potential on a cassette magnetic recording tape at half hourly intervals. Details of the EIL and NERA instrument systems including description, operation and maintenance aspects, are provided in the instrument manuals (3,4); these are briefly reviewed in the following section. Photographs of the instruments are shown in Figures 3a and 3b.

### 2.2. DESCRIPTION OF EQUIPMENT

#### 2.2.1 EIL System

The EIL model 15A meter has two linear oxygen scales of 0-100% and 0-200%, where 100% represents the concentration of oxygen in water saturated with air, at a pressure of 760 millimeters of mercury. A third scale is calibrated in temperature from -5 to +30<sup>0</sup>C and is used to indicate the water temperature\*. The dissolved oxygen electrode (model 1511) gives an output current in proportion to the concentration of oxygen present in water,

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\* as measured by the temperature electrode (Model 1512) in the water.

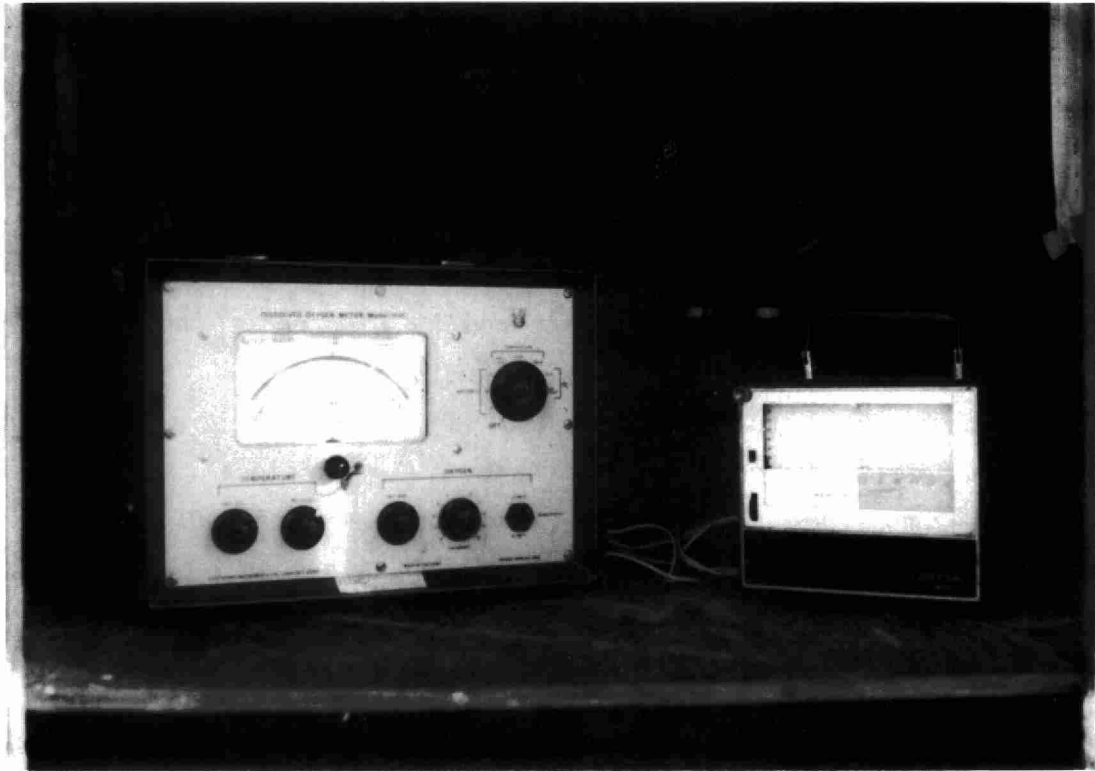


Figure 3a - EIL Meter and Rustrak Recorder



Figure 3b - NERA Model 4

and this is indicated on the EIL model 15A meter, on a scale directly calibrated in oxygen percentage saturation. Because the output current of the electrode varies markedly with temperature, automatic temperature compensation for this variation has been provided within the temperature probe by the use of a thermistor. The thermistor has a suitable temperature coefficient which is used to vary the sensitivity of the oxygen amplifier. The Rustrak recorder prints the currents received from the EIL meter through the impinging action of its two styli which are driven by a striking bar against the pressure-sensitive paper. The recorder output is a series of dots appearing as a continuous line.

#### 2.2.2 NERA System

The NERA model-4 system consists of two classes of equipment:

- (i) basic field equipment, which is taken to the specific site from which data are to be collected; and
- (ii) office equipment, used in the office environment for processing of the field data.

The field equipment is portable and environmentally packaged. It consists of the following subsystems:

- (i) A sonde assembly which houses the in-situ type sensors and protects them from debris without interfering with the environment to be sensed.
- (ii) A signal cable which carries reference voltages to the sensors and power to the DO stirrer motor and preamplifiers in the sonde assembly. The cable also carries output signal voltages from the sonde to the signal conditioner.

(iii) The signal conditioner provides reference voltage signals to those probes that require them, and maintains power distribution and electrical isolation between probe sensing subsystems. The signal conditioner also receives analog output signals from the sonde assembly, performs temperature compensation corrections to sensor signals as required and standardizes the signals prior to input into the control digital data logger. A multi-scale meter on the face of the signal conditioner provides a quick-look display of incoming data.

The control-digital logger (C/DDL) controls the timing sequence of the overall system, determining when power is applied to probes that require some settling time, initiating the DO stirrer sufficiently ahead of data scans, and initiating data scanning intervals. The C/DDL performs analog to digital conversion of the analog data signals received from the signal conditioner. The digitized data signals are recorded on a magnetic tape in such a time sequence manner as to permit subsequent automatic handling and processing of the data by playback systems.

The present office equipment consists of a DTR-5 playback/interface unit and software package described in Chapter 3. The DTR-5 playback interface unit provides for playback via a cassette recording/ playback device similar to that used in the C/DDL. When interconnection to a computer terminal is provided, the raw data on the cassette tape is transmitted via conventional telephone lines to disk or tape components of the Ministry's computer facility. The software provides for storage of the raw data, conversion of the raw data into engineering units, error checks, storage of the processed data and display of the processed data in various formats as described in Chapters 3 and 4.



Figure 4a - EIL Shelter

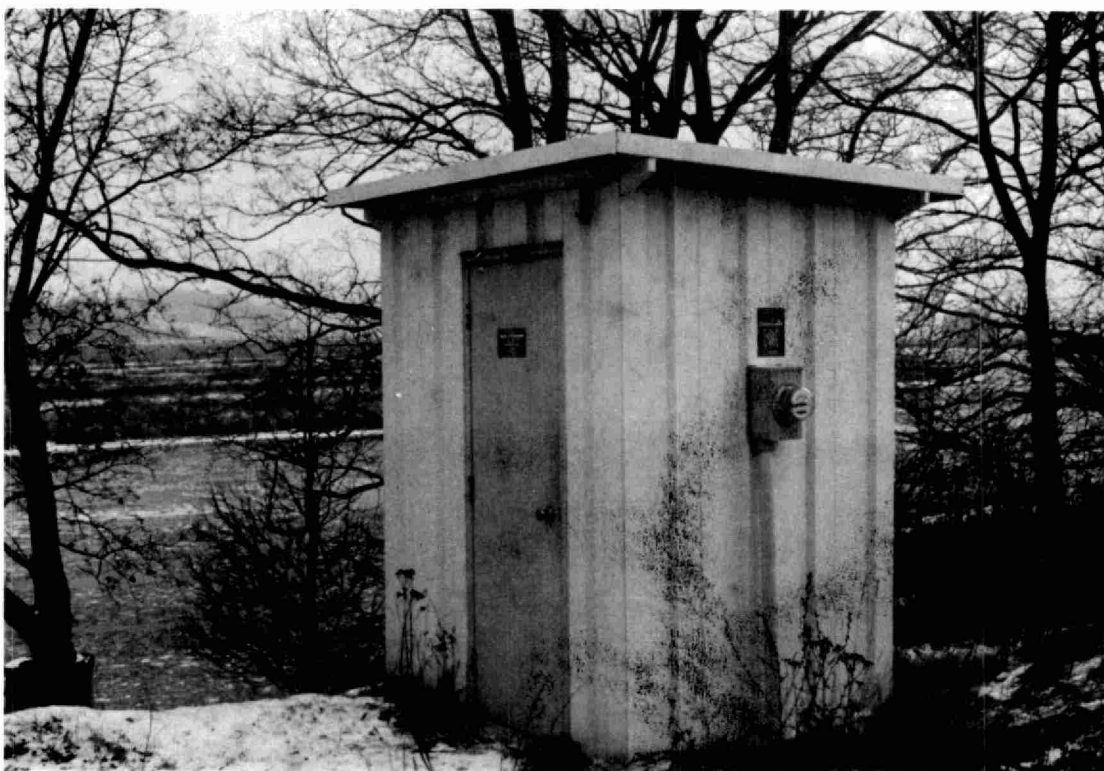


Figure 4b - NERA Shelter

### 2.3 INSTALLATION OF INSTRUMENT SYSTEMS

Each EIL instrument system is housed in a standard "dog-house" which is bolted on top of a plywood box base (79-cm x 79-cm x 91-cm), anchor-bolted to a 10-cm thick concrete pad as shown in Figure 4a. A 5-cm diameter plastic tubing is buried from inside the concrete pad to the edge of the water, where the tube is connected to a 5-cm cast iron conduit. The temperature and dissolved oxygen probes are pulled through this plastic tube and are connected to the EIL meter inside the "dog-house". In the stream, the probes are suspended in water with a plastic boat float, and are protected from algal fouling by an upstream screen held vertically against the flow by electrical fence rods. Details of an EIL monitoring system installation are shown in Figure 5.

The NERA instrument system is housed in a 193-cm x 173-cm ARMCO shelter on a 46-cm thick concrete base as shown in Figure 4b. A 5-cm polyethylene conduit runs from the shelter to a stilling well which houses the sonde (probe) assembly. The stilling-well-sonde housing is constructed of a steel-ridged culvert with an attached 15-cm diameter plastic water pipe. A submersible pump near the base of the culvert draws water into the culvert and discharges it downstream through a 3-cm ABS plastic pipe. Figure 6 shows the installation features of the NERA monitoring system.

### 2.4 OPERATION AND MAINTENANCE ASPECTS

Each instrument site is visited once or twice a week when the following checks and adjustments are carried out, as required:

- (1) Independent measurement of each water quality parameter and comparison with the meter reading including resetting of reading, if required.

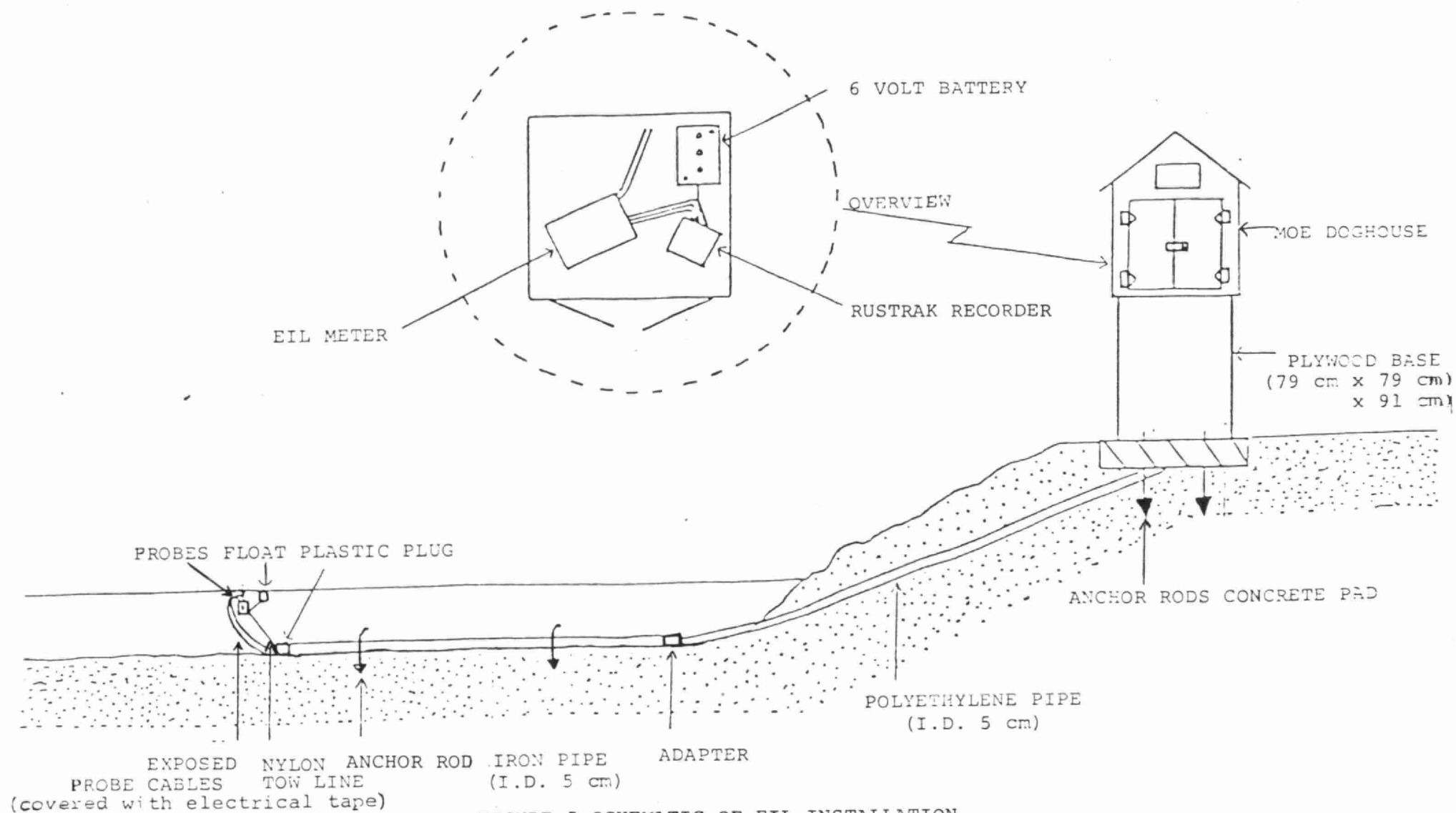


FIGURE 5. SCHEMATIC OF EIL INSTALLATION

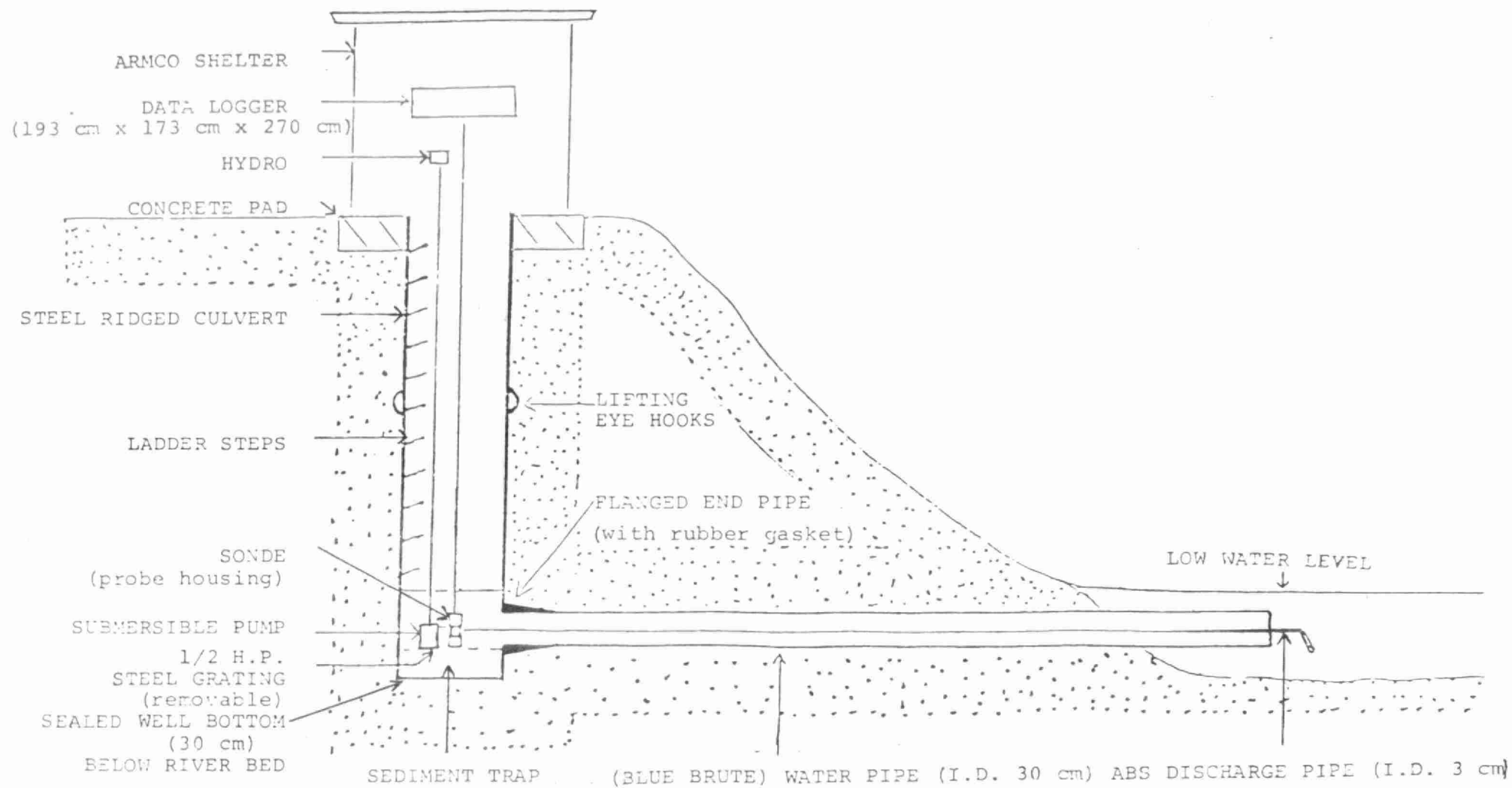


FIGURE 6. SCHEMATIC OF NERA INSTALLATION

- (2) Cleaning slime and algal growth from probe membrane and algal screen.
- (3) Recharging or replacement of battery.

Both the meter readings and independently measured values are entered in a table along with the date and time; this information is used to correct the data for calibration errors during the processing of the records as described in Chapter 3. Other checks and adjustments are also noted in the table. Annual reports describe, in more detail, the various aspects of operation and maintenance of the continuous monitors in the Grand River Basin (5,6).

### 3. DATA PROCESSING PROCEDURES

#### 3.1 EIL DATA PROCESSING

DO and temperature values output by the EIL instruments are recorded on a dual-strip chart by a RUSTRAK recorder. Each chart can contain a maximum of about 63 days' data. The DO and temperature values recorded continuously on the strip chart are digitized at predetermined time intervals (i.e., converted from chart co-ordinates to numerical form on IBM punched cards). Briefly, the hardware involved in the digitization process consists of an electrically charged (digigrade) table top and a moveable cursor which is moved along a chart tracing which translates chart points into x and y co-ordinates relative to a fixed origin on the table. The system is linked to an IBM key-punch machine which produces punched data from the chart co-ordinates.

The time (abscissa) intervals are fixed for a given chart and are taken as one hour for the period of May to November, when diurnal variations in DO are significant. For the remainder of the recorded year, an interval of two hours is found to be adequate as the diurnal DO variation is much smaller in magnitude. These time intervals are based on an analysis of the measured diurnal DO profiles, and an optimal choice of interval so as to minimize the possibility of misrepresenting the daily minimum and maximum in the process of reduction of data from a continuous record.

The digitized data of the DO and temperature curves are converted from RUSTRAK chart scale units to real units (DO in % saturation and temperature in  $^{\circ}\text{C}$ ) by the computer program HG DOEIL developed by one of the authors (T.P.H. Gowda of the Water Modelling Section) with assistance from J.R. Eddie of the Hydrology and Monitoring Section. The procedures involved in the preparation of the data for input to the computer program are documented in a manual (7), prepared by the Hydrology and Monitoring Section.

Figure 7 shows a schematic sequence of the EIL data processing. The steps involved in the data processing procedure are summarized below:

- 1) Digitization of the points on the DO and temperature curves at a predetermined time interval (also known as sampling interval).
- 2) Translation of the digital data to DO and temperature values, and time-sequencing of each data value.
- 3) Application of correction factors to each value of DO and temperature to account for any errors recorded during field inspection of the instruments.

Two types of errors may occur:

- (i) calibration differences, and
- (ii) improper resetting of the recorder needles.

In the former case, a correction is applied on the assumption that the variation in the magnitude of error in DO or temperature is linear with time; the correction is calculated from

$$S_{t_i} = \frac{S_{t_2} (t_i - t_1)}{t_2 - t_1} ; \quad (t_1 < t_i < t_2)$$

where  $S_{t_i}$  = estimated correction for parameter at time  $t_i$ ;  
 $S_{t_2}$  = difference between recorded parameter value and independent measurement at end of recording interval;  
 $t_1$  = beginning of recording period;  
 $t_2$  = end of recording period.

In the case of improper resetting of a recorder needle, a uniform correction is applied. A further discussion of the calibration correction procedure is given in Section 3.3.

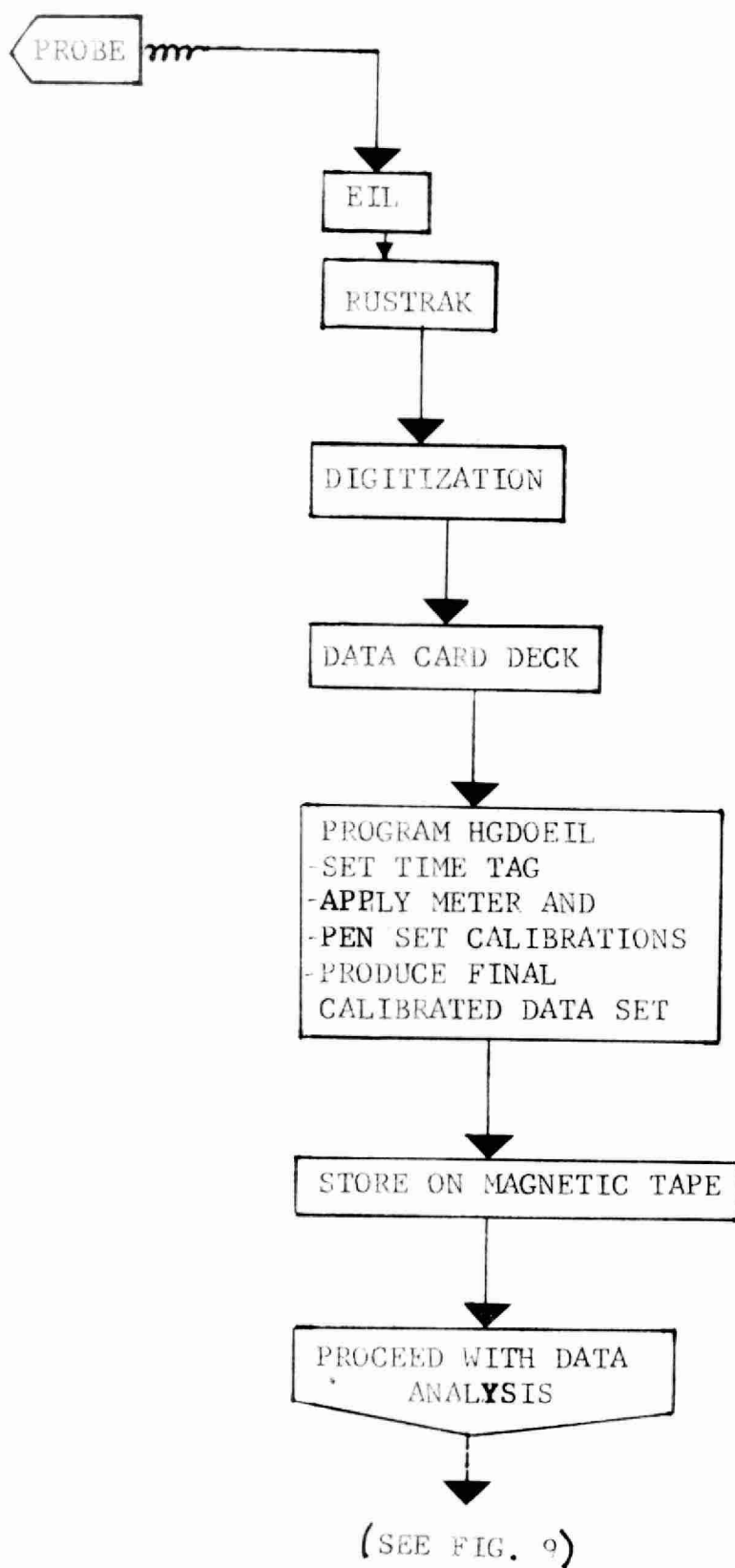


Figure 7 - EIL DATA PROCESSING SEQUENCE

- 4) Storage of the corrected data on a computer tape.  
Only the initial hour, day and year (i.e., starting time and date) are stored on the tape along with the sampling interval, since the time interval is constant for any one EIL data set. The meter calibration data are also stored on the tape.
- 5) If there are any breaks in the chart recordings, negative numbers are substituted for data as follows:

-888.00 for DO; and  
-999.00 for Temperature

Although this procedure can be used for any length of time, it is usually limited to 90 hours or less. If the break extends for longer periods, then the data are treated as a separate set with a new starting date.

6. When a reasonable number of tapes have been created for each EIL station (usually 7 or more), the data are recopied to a single tape and the older tapes erased.

The data stored on tape are retrieved by a program in which the data points are automatically time-tagged using the stored starting time/date and sampling interval. A sample output of the DOEIL program is presented in Table 2.

INSTRUMENT NO.: 4

CHART NO.: 4

YEAR	DAY	HOURL	TEMP CEL.	DISSOLVED OXYGEN MG/L % SAT.
1978	143	10.0	15.75	10.41 105.52
1978	143	11.0	16.23	11.23 114.97
1978	143	12.0	16.93	11.61 120.73
1978	143	13.0	17.41	11.78 123.74
1978	143	14.0	17.89	11.69 124.02
1978	143	15.0	17.90	11.80 125.21
1978	143	16.0	18.15	11.59 123.66
1978	143	17.0	18.40	10.88 116.63
1978	143	18.0	18.18	10.09 107.74
1978	143	19.0	18.20	9.17 97.90
1978	143	20.0	17.76	8.33 88.08
1978	143	21.0	17.78	7.66 81.05
1978	143	22.0	17.79	7.42 78.59
1978	143	23.0	17.81	7.27 77.05
1978	143	24.0	17.60	7.25 76.42
1978	144	1.0	17.61	7.18 75.78
1978	144	2.0	17.40	7.07 74.25
1978	144	3.0	17.19	6.96 72.71
1978	144	4.0	16.98	6.93 72.09
1978	144	5.0	16.77	6.81 70.56
1978	144	6.0	16.55	6.87 70.83
1978	144	7.0	16.11	7.67 78.35
1978	144	8.0	16.36	8.28 85.01
1978	144	9.0	16.83	9.72 100.88
1978	144	10.0	17.54	10.74 113.10
1978	144	11.0	18.25	11.72 125.28
1978	144	12.0	18.72	12.39 133.74
1978	144	13.0	18.97	12.93 140.32
1978	144	14.0	19.68	12.85 141.49
1978	144	15.0	20.61	12.47 139.97
1978	144	16.0	20.63	11.93 133.94
1978	144	17.0	20.85	11.22 126.03
1978	144	18.0	20.20	10.28 114.41
1978	144	19.0	19.76	9.23 101.82
1978	144	20.0	19.78	8.09 89.25
1978	144	21.0	19.34	7.60 83.14
1978	144	22.0	19.58	7.18 78.87
1978	144	23.0	19.37	7.15 78.24
1978	144	24.0	19.39	7.09 77.61
1978	145	1.0	19.40	7.03 76.98
1978	145	2.0	18.96	6.87 74.55
1978	145	3.0	18.98	6.81 73.92
1978	145	4.0	18.54	6.82 73.30
1978	145	5.0	18.32	6.79 72.67
1978	145	6.0	18.11	7.27 77.46
1978	145	7.0	18.13	7.97 85.00
1978	145	8.0	18.39	9.07 97.16
1978	145	9.0	18.85	10.53 113.98

TABLE 2: SAMPLE OUTPUT OF HGDOEIL PROGRAM

## 3.2 NERA DATA PROCESSING

### 3.2.1 Description of Computer Programs

A linked series of FORTRAN programs are used to process the data from NERA cassette tapes, and to printout and store the results. These programs are modified versions of programs originally written for use with NERA lake water quality monitors maintained by the Lake Systems Unit of the Water Resources Branch. A complete documentation of the programs is available from the River Systems Unit (10).

The sequence involved in processing the NERA data records is shown schematically in Figure 8. The main functions of the individual computer programs are summarized below:

<u>PROGRAM</u>	<u>FUNCTION</u>
NERA 1	<ul style="list-style-type: none"><li>- selection of valid number of channels (parameters)</li><li>- selection of scale for each channel</li><li>- read in data from cassette tape to computer disk storage</li></ul>
NERA 2	<ul style="list-style-type: none"><li>- read the number of lines of data to be deleted at the beginning and end of cassette tape record and replace with "888888"</li><li>- check for agreement between actual and expected amount of data and allow user cancellation of run if discrepancy is too large</li><li>- selection of valid channels (parameters), when one or more probes is not functional</li><li>- select value limit for each parameter for editing out-of-range values</li></ul>
NERA 3	<ul style="list-style-type: none"><li>- edit for erroneous characters in cassette tape record</li><li>- edit for out-of-range single values and replace with interpolated values</li></ul>

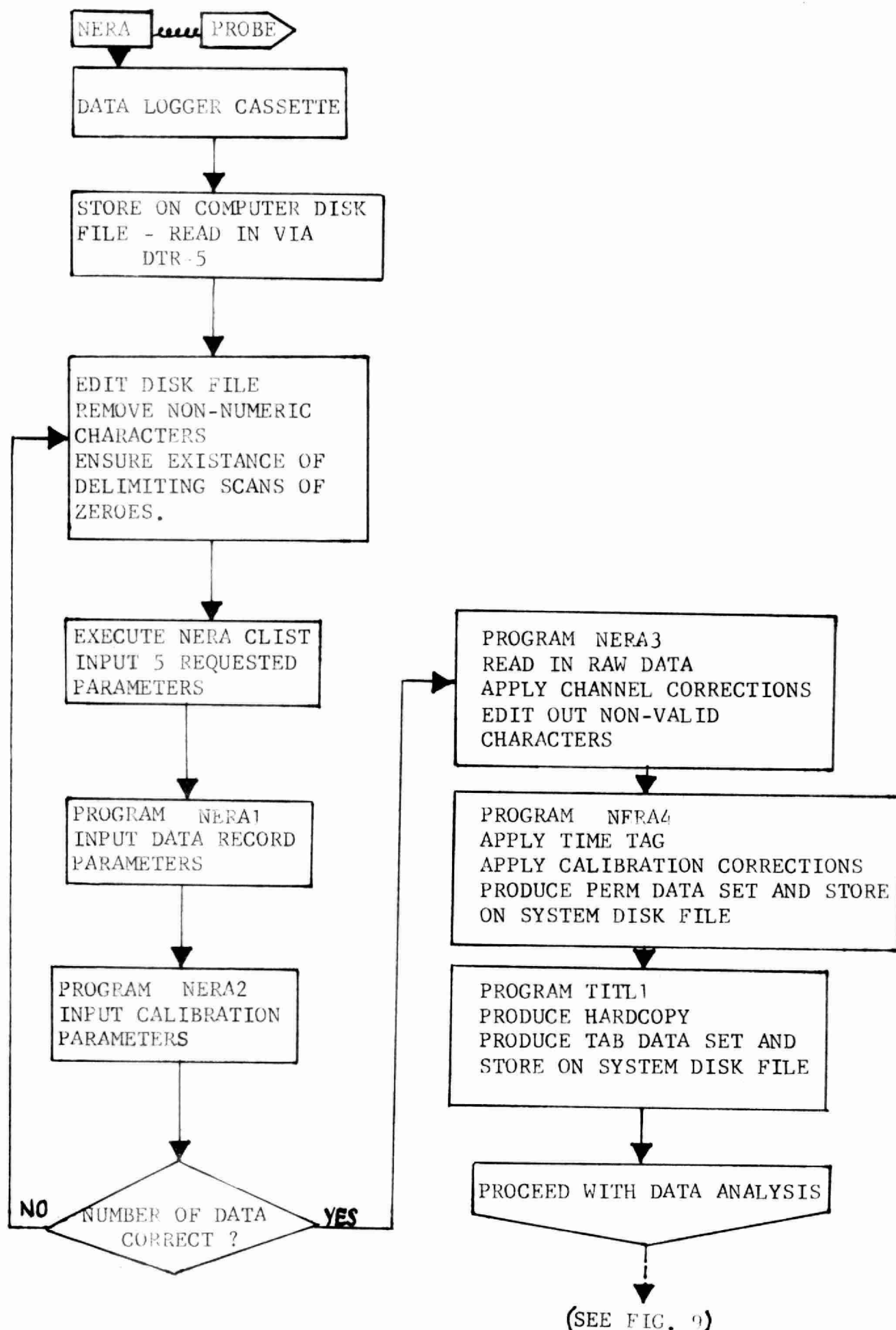


Figure 8 - NERA DATA PROCESSING SEQUENCE

- NERA 4 - input field sheet data regarding monitor adjustments (calibration) and breaks in record
- translate each valid parameter from arbitrary numbers to real units
  - apply calibration correction to data
  - apply time/date tags to each parameter set
  - store edited data in matrix and tabular form on computer tape
  - print out edited tabulated data (See Table 3 for sample output.)

The execution of these programs is done through on-line (TS0) processing and requires about 20 minutes of connect time per cassette record, plus about one hour to transmit data from cassette to computer disk storage. The data on cassette tape is read into computer storage through a NERA Playback/Interface unit model DTR-5. This is a 110 baud playback unit connected between a standard printing terminal and a telephone modem, which provides the computer interface. The tape can also be replayed off-line.

### 3.2.2 Time Sequencing

Each cassette data record starts and ends with a row of zeros ("0's") entered by the field personnel changing the tape. When the tape is submitted for computer processing, the magnetically encoded data are transmitted from the cassette to a computer disk file. The delimiting "0" lines serve as one check that the data set is transmitted in its entirety. The processing routine also then counts the number of data in the disk file and prints out a comparison with the number of data expected, based on the sampling interval, and the starting and ending dates and times.

In a normal processing run, the data are then time-tagged sequentially beginning at the start date and time, by adding

## SPEED RIVER NERA AT GLEN CHRISTIE

DATE	TIME	TEMP(CEL.)	COND(25C)	PH	DO	MG/L	D.O. %	O.R.P.MV
1978	149	20.00	24.55	310.00	7.75	4.76	57.72	450.00
1978	149	20.30	24.40	309.00	7.71	4.30	52.00	458.00
1978	149	21.00	24.20	309.57	7.67	3.84	46.14	462.00
1978	149	21.30	24.00	308.57	7.65	3.44	41.18	464.00
1978	149	22.00	23.80	307.15	7.65	3.20	38.28	464.00
1978	149	22.30	23.55	306.15	7.64	2.96	35.24	464.00
1978	149	23.00	23.25	305.44	7.63	2.84	33.56	463.00
1978	149	23.30	23.00	304.72	7.62	2.68	31.48	462.00
1978	149	24.00	22.70	304.01	7.61	2.56	29.84	460.00
1978	150	0.30	22.40	304.59	7.62	2.46	28.62	459.00
1978	150	1.00	22.10	305.87	7.62	2.40	27.72	458.00
1978	150	1.30	21.80	306.16	7.61	2.38	27.28	459.00
1978	150	2.00	21.50	307.45	7.61	2.38	27.30	461.00
1978	150	2.30	21.20	308.74	7.61	2.40	27.30	463.00
1978	150	3.00	20.90	309.02	7.61	2.42	27.32	466.00
1978	150	3.30	20.65	309.31	7.60	2.46	27.58	469.00
1978	150	4.00	20.45	308.60	7.60	2.46	27.42	473.00
1978	150	4.30	20.20	307.89	7.59	2.46	27.46	476.00
1978	150	5.00	20.05	307.17	7.59	2.48	27.56	479.00
1978	150	5.30	19.90	305.46	7.60	2.52	27.86	482.00
1978	150	6.00	19.85	303.75	7.60	2.58	28.46	484.00
1978	150	6.30	19.85	302.04	7.61	2.76	30.40	487.00
1978	150	7.00	19.90	299.32	7.63	3.08	34.14	489.00
1978	150	7.30	20.05	296.61	7.67	3.58	39.74	490.00
1978	150	8.00	20.25	293.90	7.71	4.18	46.54	490.00
1978	150	8.30	20.50	291.19	7.77	4.78	53.46	486.00
1978	150	9.00	20.80	289.47	7.82	5.34	60.26	482.00
1978	150	9.30	21.10	286.76	7.85	5.82	66.02	477.00
1978	150	10.00	21.45	286.05	7.89	6.26	71.46	472.00
1978	150	10.30	21.75	284.34	7.93	6.66	76.42	467.00
1978	150	11.00	22.05	283.62	7.97	7.06	81.46	462.00

TABLE 3: SAMPLE OUTPUT OF NERA4 PROGRAM

the sampling interval to the time tag of each subsequent row of data, and the final row of data will then be tagged with the end date and time. In the event of a malfunction of the NERA data logger during a recording period, the field personnel restart the cassette tape and punch in a row of "0's", recording the reset time and date on the field sheet. During the computer processing, this row of "0's" is searched for by the program and when encountered, the subsequent data are re-tagged starting with the reset time.

### 3.3 COMMENTS ON AUTOMATED DATA PROCESSING

The present system employed in the processing of continuous monitor data results from a good co-operative effort between the field and office staff, and has produced a very reliable data base for the period 1975-1978. However, some minor problems occasionally arise which require special handling of the data:

#### (a) Data Calibration Correction

As discussed above, when instrument decalibration occurs, a linear correction over time can be applied. The possibility exists however, that the deviation is non-linear, either because the deviation occurs intermittently, or because the deviation varies with the time of day. In the case of an intermittent, or sudden change in DO, for example that resulting from a sudden fouling of probes by a drifting mat of algae, an EIL chart record will clearly show the effect; the personnel digitizing the data can then interpolate values on the chart during the problem period. When this is done, the calibration procedure is bypassed in the data processing. When a similar event occurs during the recording of NERA data, the absence of a chart record makes such sudden anomalous DO changes less obvious. A computer routine to detect such periods is being considered.

Every effort is made to check the accuracy of the data from both types of monitors, and although automated data processing is necessary to handle the large amounts of data collected, the system is flexible enough that data are corrected manually when necessary.

(b) NERA Data Timing

EIL data are recorded originally continuously on a chart and can be visually checked for time continuity. However, NERA data are not time-tagged until the cassette data record is processed. This has led to problems on a few occasions.

Over a period of months, the sampling interval in one NERA monitor gradually lengthened from 30 to 34 minutes. This would have led to large discrepancies in time-tagging of data if it had not been noticed during the data processing. This occurrence, together with the occasional loss of some data during transmission of the cassette data to computer disk, led to modifications to the program NERA 2 which now ensures that the entire set of data is received on disk, and is properly time-tagged.

Secondly, data logging equipment malfunctions, or running out of tape, has caused breaks in the data record. The program NERA 4 has the capability of re-tagging data points according to information supplied on the field sheets, in this eventuality. However, when both of the above mentioned problems also occur in the same recording period (which occurred on one occasion), it is difficult to detect the problem and produce reliably timed data.

The following improvements in NERA data processing procedures are therefore suggested:

- (i) Specification and implementation of a continuous means of verifying the time accuracy of the NERA data logging

system. Any sporadic malfunctions or gradual change in the scanning interval would thus be immediately obvious to field personnel and could be rectified without any delay. The present system of having the amount of data verified by the data processing system ensures the timing accuracy of the data, but there is an unavoidable time lag in reporting any discrepancies to the field personnel.

- (ii) Further data processing program modifications to ensure that NERA data are corrected appropriately where calibration corrections must be made.

### 3.4 ACCURACY OF PROCESSED DATA

The accuracy of the processed data (i.e., outputs of the HGDOEIL and the NERA computer programs) is dependent on the magnitudes of the potential instrumental errors as well as manual errors. A brief description of the results of limited investigations on these error sources is presented below.

#### (a) Instrumental Errors:

The specifications for the probes used in the EIL meter state that the accuracy of temperature measurements is within  $\pm 1.5^{\circ}\text{C}$ , and that the DO readings are accurate to within  $\pm 5\%$  of the scale readings for solutions within  $10^{\circ}\text{C}$  of a previously selected temperature (3). The specifications for the temperature probes of the NERA instrument system state that the overall accuracy of the output data signal is  $\pm 0.2^{\circ}\text{C}$  for the temperature range  $-5^{\circ}\text{C}$  to  $25^{\circ}\text{C}$ ,  $\pm 0.4^{\circ}\text{C}$  for the range  $25^{\circ}\text{C}$  to  $45^{\circ}\text{C}$ , and the overall accuracy of the meter reading is stated to be the same as that of the output data signal  $\pm 0.25^{\circ}\text{C}$  (4). The output data signal of the NERA DO probe is specified to have an overall accuracy of  $\pm 2\%$  of the reading; the overall accuracy of the meter reading is specified to be ( $\pm 2\%$  of the reading  $\pm 0.5\%$  of the range).

Investigations were carried out to determine, under field conditions, the differences between the EIL DO probe output and the RUSTRAK recorder chart readings. The absolute differences of the temperature outputs were found to be within  $0.5^{\circ}\text{C}$  at all seven EIL stations, except for differences of up to  $3^{\circ}\text{C}$  at times during early spring and late fall. The DO readings were found to be accurate to within  $\pm 1\%$  saturation.

Results of investigations at the two NERA sites showed that the temperature recordings were accurate to within  $\pm 0.15^{\circ}\text{C}$ , whereas the accuracy of the DO readings was within  $\pm 0.1$  mg/L.

(b) Manual Errors

These errors apply to the EIL data and are generated during the digitization of the chart records. Errors are introduced when the cursor is not centered exactly at the desired points on the DO or temperature curve. In order to determine the magnitude of this error, separate samples (each consisting of 24 data points) were selected. A comparison of the DO values of the processed data (i.e., computer outputs) with the corresponding chart readings showed an absolute mean difference of about  $1\frac{1}{2}\%$ , with a range of  $-2\%$  to  $+3\%$ ; Generally, a faster rate of digitization was associated with a larger discrepancy. Under normal conditions, an accuracy of 1 to  $2\%$  ( $\pm$ ) is achieved.

(c) Total Error

Based on the above facts, the processed data is likely to be accurate to within  $\pm 1^{\circ}\text{C}$  for temperature and  $\pm 4\%$  saturation for dissolved oxygen.

#### 4. STATISTICAL AND PROBABILISTIC ANALYSIS OF DATA

##### 4.1 GENERAL DETAILS OF DATA ANALYSIS

Since the inception of the continuous monitoring networks in the Grand River Basin in 1975, a vast amount of data has been generated on DO, temperature, oxidation-reduction potential, pH and conductivity. As an example, with a sampling interval of one hour a record of one year would result in the generation of 8760 values of each parameter at each monitoring station. In order to summarize the data in a compact form without a significant loss of the most important characteristics of the data records, the statistical and probabilistic data analysis procedures, described in the following subsections, have been used. This approach is also consistent with the requirements of the continuous monitoring data for calibration and verification of the Grand River water quality simulation model. As stated earlier, this analysis includes the data generated at the seven stations installed in 1975 for the recording period May 1975 - December 1978.

A schematic summary of the statistical and probabilistic data analyses is presented in Figure 9. Brief descriptions of the data analysis programs are presented below.

##### 4.1.1 Daily Statistics

By considering a daily period of 24 hours from the midnight of one day to the midnight of the next day (EST), the daily statistics were computed by the program DAILY, which retrieves an EIL or NERA dataset and provides the following output summary:

- (i) daily mean value of temperature ( $^{\circ}\text{C}$ ) and DO (mg/L);
- (ii) daily minimum value of temperature ( $^{\circ}\text{C}$ ) and DO (mg/L), and times of occurrence;
- (iii) daily maximum value of temperature ( $^{\circ}\text{C}$ ) and DO (mg/L), and times of occurrence.

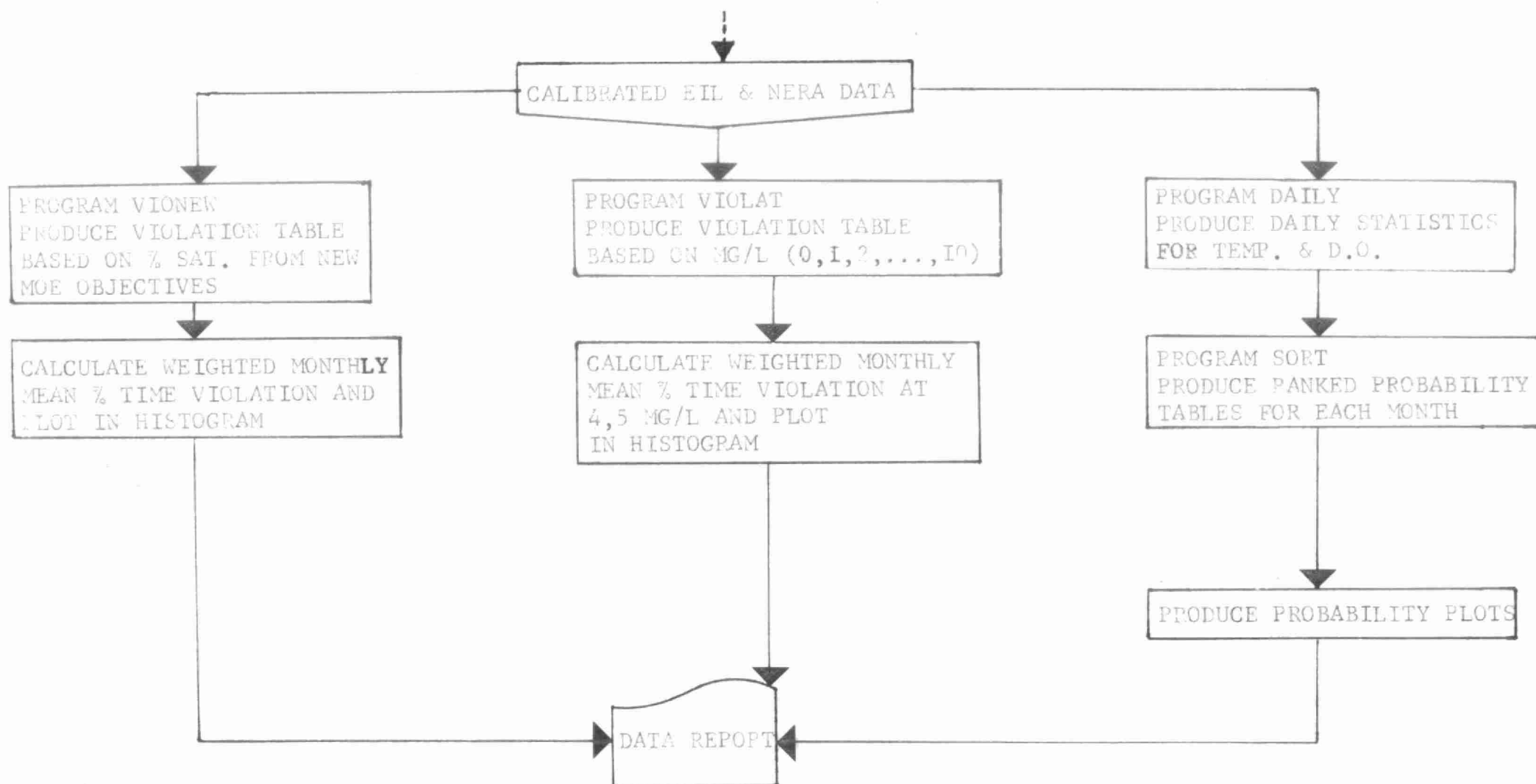


Figure 9 - CONTINUOUS MONITORS RAW DATA ANALYSES

A sample output of the DAILY program is presented in Table 4. The statistical summary tables for the period May 1975 - December 1978, are on file and are available on request. Although the program is set up to print output summaries of only temperature and DO at present, it has the capability of producing similar output for the additional parameters of conductivity, pH and redox potential, recorded by the NERA monitors.

#### 4.1.2 Probabilistic Analysis

Part of the output from the DAILY program was used to derive exceedance probability plots for DO. The percentage probability of exceedance of each value was calculated by ranking the data for a given month in descending order of DO concentration, and using the equation

$$p = \frac{100 \ m}{N + 1}$$

where p = percentage probability of exceedance of a given value;

m = ranking of each data value; and

N = total number of data points in the month.

The probabilistic analysis was performed with minimum daily and mean daily DO concentrations for all seven stations for the recording period May 1975-December 1978. The computations were carried out by using the program SORT.

A preliminary evaluation of the arithmetic and logarithmic probability plots of the minimum and mean daily DO data indicated a straight line relationship on the latter plot; this suggests that, in general the data conform to a log-normal distribution. Based on this, the results were plotted on logarithmic probability paper, and straight lines of best fit

## GRAND RIVER AT GLEN MORRIS

(STATION - 4)

DATE YR	DAY	TEMPERATURE (DEG. CEL.)					D I S S O L V E D				TIME HOUR	D O X Y G E N			TIME HOUR
		MEAN	MAX	TIME	MIN	TIME	MEAN	%	MAXIMUM	%		MINIMUM	%		
				HOOR		HOOR	MG/L		MG/L			MG/L			
1978	143	*	17.59	18.40	17.00	15.75	10.00	9.88	104.09	11.80	125.21	15.00	7.25	76.42	24.00
1978	144		18.51	20.65	17.00	16.11	7.00	9.18	99.07	12.93	140.32	13.00	6.81	70.56	5.00
1978	145		20.18	23.10	16.00	18.11	6.00	9.40	105.28	13.59	155.81	13.00	6.33	69.57	23.00
1978	146		21.19	23.69	17.00	18.52	6.00	8.48	96.87	13.04	151.74	13.00	3.90	44.34	24.00
1978	147		23.93	26.45	14.00	21.69	3.00	6.84	82.86	11.11	136.88	13.00	3.75	43.07	4.00
1978	148		24.17	25.54	14.00	23.04	6.00	6.54	78.99	8.88	109.53	15.00	4.72	56.04	23.00
1978	149		23.42	25.12	15.00	22.13	6.00	5.90	70.30	8.61	104.94	14.00	3.80	44.19	24.00
1978	150		24.32	26.29	15.00	22.14	3.00	6.41	77.96	9.64	120.78	15.00	3.93	45.49	1.00
1978	151		23.39	25.76	15.00	19.92	24.00	7.43	88.55	10.29	127.75	15.00	4.66	51.59	24.00
1978	152		21.28	25.00	14.00	18.69	7.00	7.21	82.86	10.40	125.35	13.00	4.69	51.07	2.00
1978	153		20.29	21.87	15.00	17.89	24.00	7.10	79.51	9.30	107.04	14.00	5.19	55.06	24.00
1978	154		18.20	21.73	17.00	15.40	24.00	8.18	88.39	12.14	135.30	14.00	5.01	52.70	1.00
1978	155		16.58	19.66	15.00	13.86	3.00	8.33	86.79	11.45	125.21	12.00	5.67	56.19	1.00
1978	156		17.29	21.43	16.00	14.44	6.00	8.83	93.53	11.98	135.46	15.00	6.33	63.50	2.00
1978	157		17.06	21.33	16.00	13.09	6.00	9.10	95.92	12.39	139.92	15.00	5.90	60.68	24.00
1978	158	*	16.07	17.16	12.00	15.20	2.00	6.67	68.24	7.97	83.28	12.00	5.81	58.15	2.00
1978	159	*	18.56	19.33	16.00	17.30	24.00	6.80	73.21	7.62	82.84	17.00	5.81	61.53	22.00
1978	160		19.11	22.06	18.00	16.46	6.00	8.82	96.88	11.82	134.52	13.00	6.02	62.45	1.00
1978	161		19.22	22.96	17.00	15.73	5.00	9.67	106.62	13.42	154.94	15.00	6.46	69.01	24.00
1978	162		21.07	25.01	17.00	17.09	4.00	8.93	102.23	12.69	149.09	13.00	6.27	70.47	24.00
1978	163		21.07	23.40	13.00	18.14	24.00	7.97	90.83	11.77	139.57	14.00	6.02	66.55	4.00
1978	164		16.30	17.66	1.00	12.94	24.00	8.30	85.17	10.43	110.11	16.00	5.97	62.39	2.00
1978	165		14.70	18.32	17.00	12.21	3.00	9.82	97.87	12.00	123.69	13.00	7.70	72.65	24.00
1978	166		14.49	16.62	16.00	12.24	3.00	9.21	91.10	11.25	115.37	14.00	7.32	71.55	24.00
1978	167	*	13.47	13.95	1.00	13.18	5.00	7.48	72.06	7.66	73.34	6.00	7.27	70.78	1.00
1978	168		NO WATER TEMP. DATA FOR THIS DAY					NO DISSOLVED OXYGEN DATA FOR THIS DAY							
1978	169		NO WATER TEMP. DATA FOR THIS DAY					NO DISSOLVED OXYGEN DATA FOR THIS DAY							
1978	170	*	20.72	23.37	16.00	17.37	24.00	9.26	105.30	12.82	151.96	16.00	6.21	65.18	24.00
1978	171		20.49	25.05	15.00	16.33	4.00	9.60	109.21	14.20	171.90	14.00	6.11	64.03	1.00
1978	172		20.87	23.48	17.00	19.18	24.00	8.57	97.44	12.20	142.47	14.00	5.88	64.08	24.00
1978	173		19.64	22.95	15.00	17.19	7.00	9.60	106.77	14.07	164.23	14.00	5.79	61.58	3.00
1978	174		19.83	23.75	17.00	16.61	6.00	9.62	107.38	14.22	167.27	15.00	5.53	59.77	24.00

\* INCOMPLETE TEMPERATURE DATA FOR THIS DAY

\* INCOMPLETE DISS. OXYGEN DATA FOR THIS DAY

TABLE 4: SAMPLE OUTPUT OF DAILY PROGRAM

were drawn through the data points. In some cases, the data were found to deviate from the straight line of best fit in the lower and higher range of probabilities (generally less than 20% and greater than 90%). This is thought to result from a lack of homogeneity of the DO data at its more extreme values. However, these plots were found to be useful for characterization of the DO for comparison between stations and identification of seasonal trends, as well as giving a clear indication of the station DO characteristics at a glance.

#### 4.2 GRAND RIVER AT BRIDGEPORT - STATION E2

The probability distribution plots of mean daily DO and minimum daily DO for each month at station E2, the upstream control station on the main Grand River, are presented in Figure 10. It should be noted that data were not available for the period, December 1976-May 1977. Generally, the difference between the minimum and mean daily values during the winter months is very small compared with the difference during the rest of the months. The DO levels were mainly above 5 mg/L, with some exceptions during the months of June and July when the DO levels were less than 4 mg/L for up to 20% of the time. The break in the probability plot for July 1976 resulted from changes arising from a very large increase in the streamflow rate.

# BRIDGEPORT 1975

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

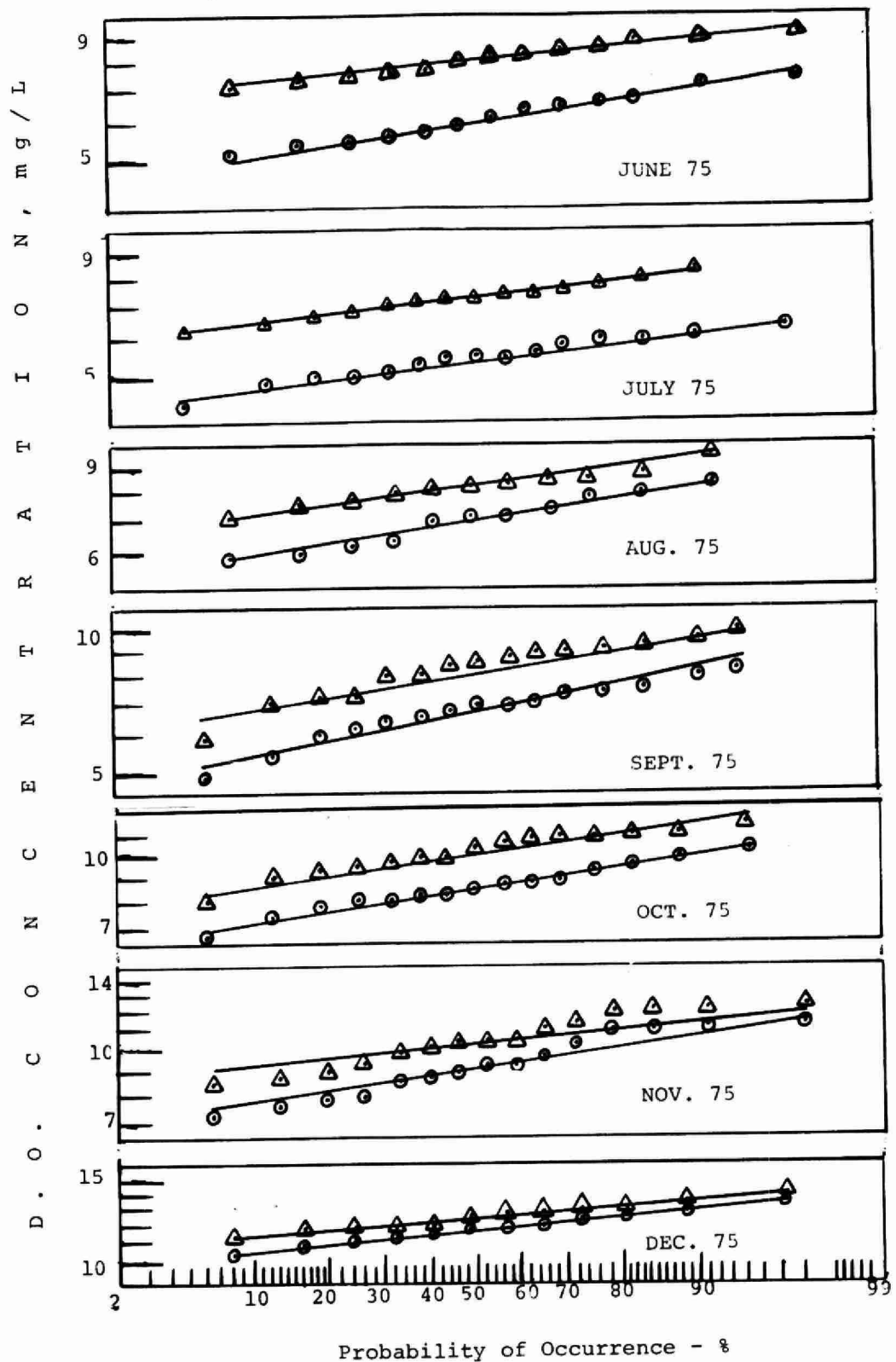


FIGURE 10 - PROBABILITY DISTRIBUTION OF D.O. LEVELS AT STATION E2 - BRIDGEPORT

# BRIDGEPORT 1976

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

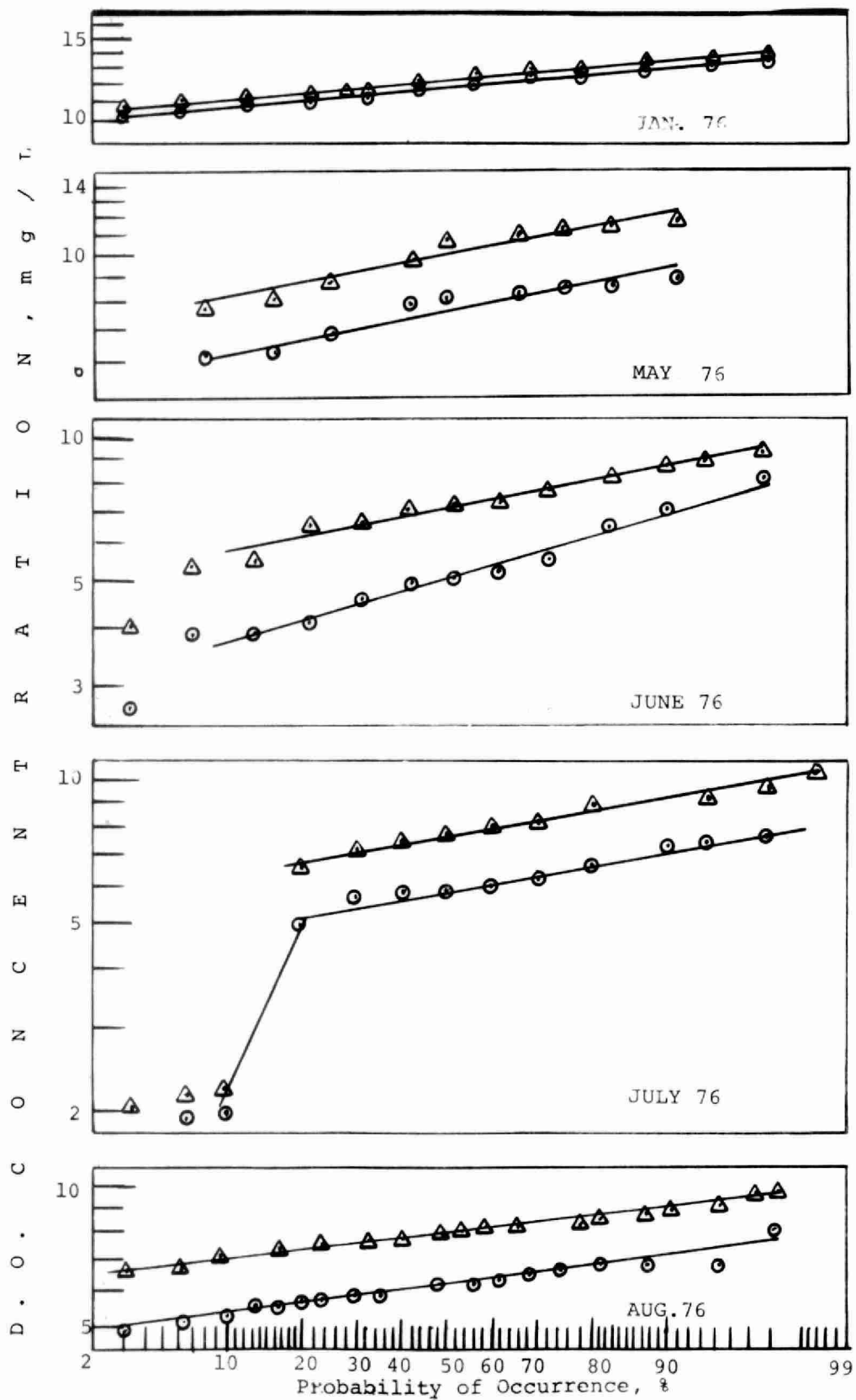


FIGURE 10 - CON'T.

# BRIDGEPORT 1976

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

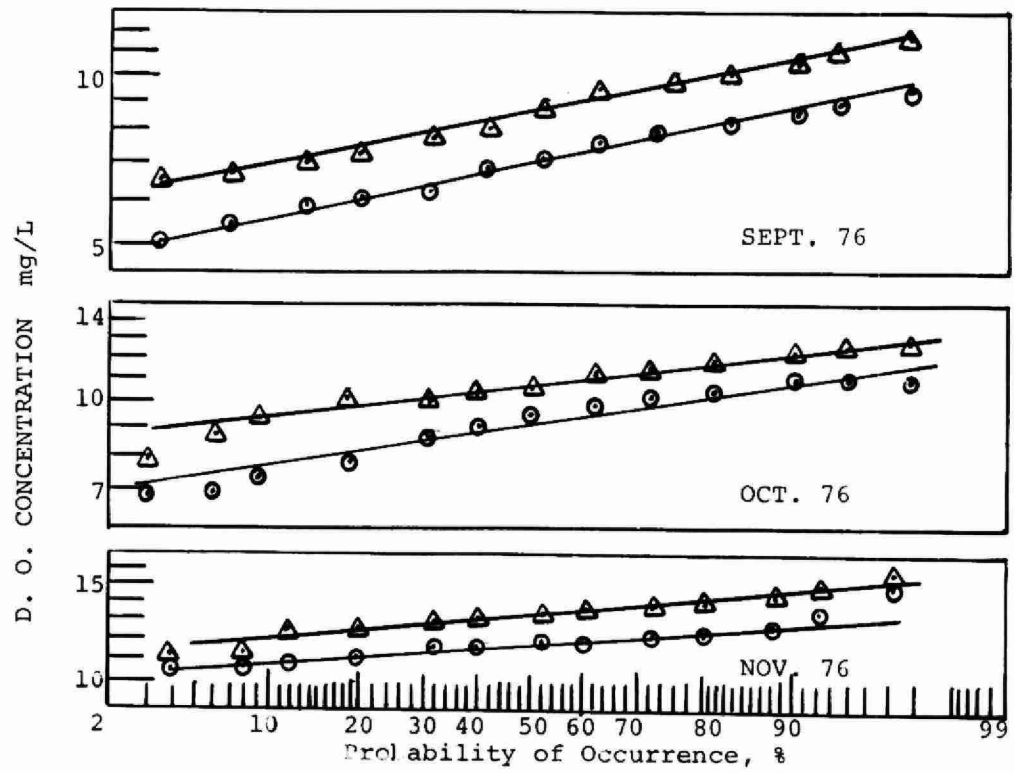


FIGURE 10 - CON'T.

# BRIDGEPORT 1977

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

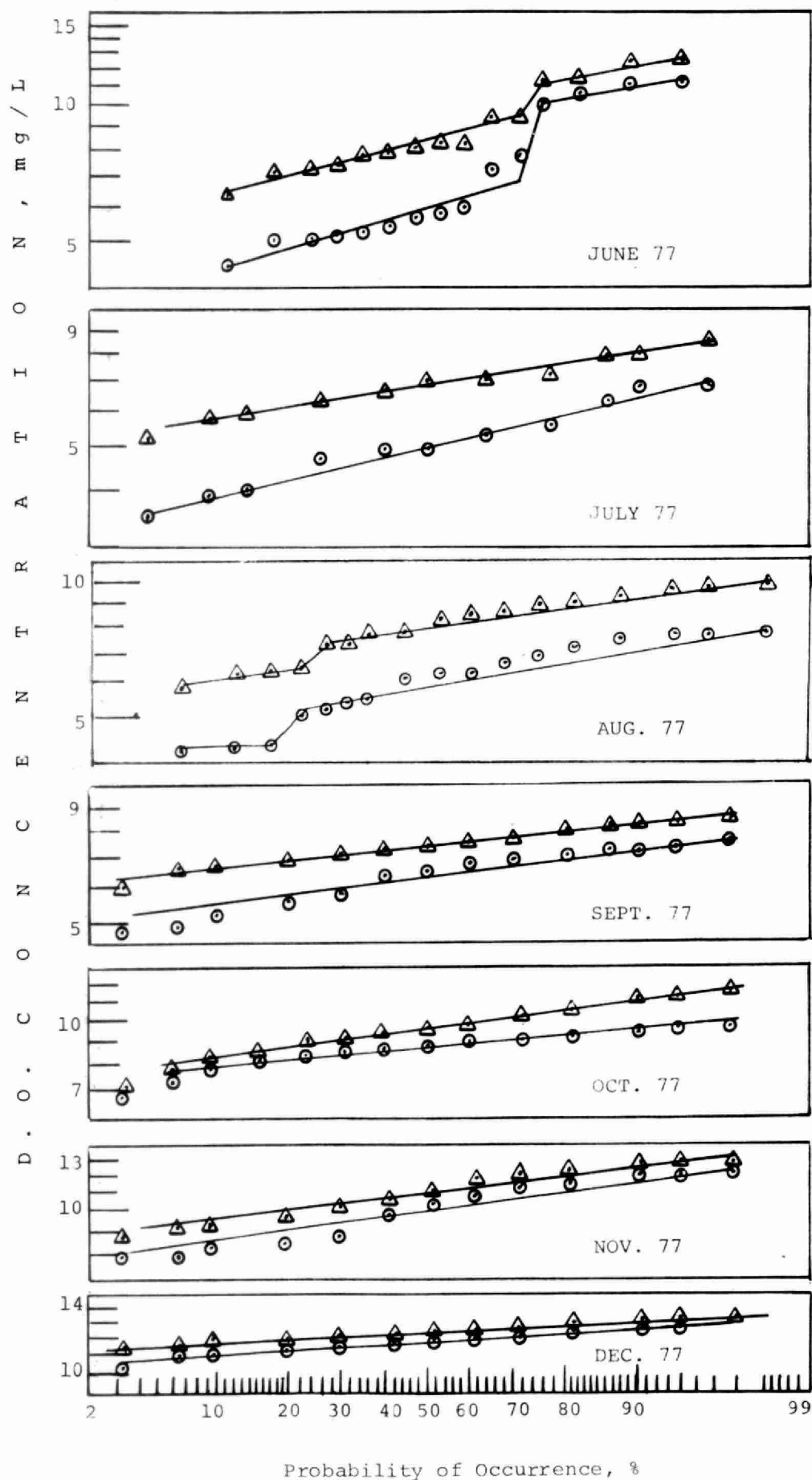


FIGURE 10- CON'T

# BRIDGEPORT 1978

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

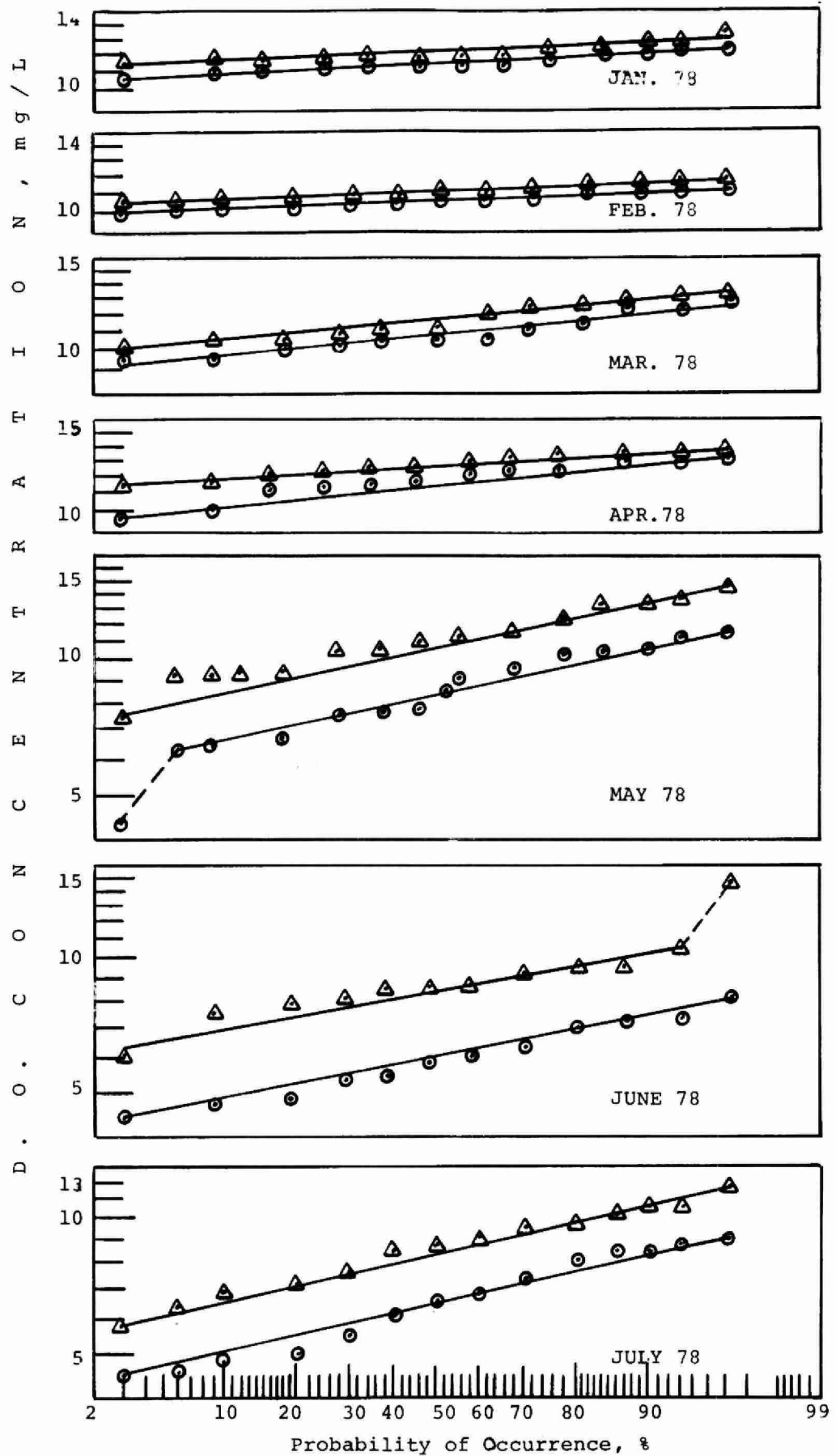


FIGURE 10 - CON'T.

BRIDGEPORT 1978

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

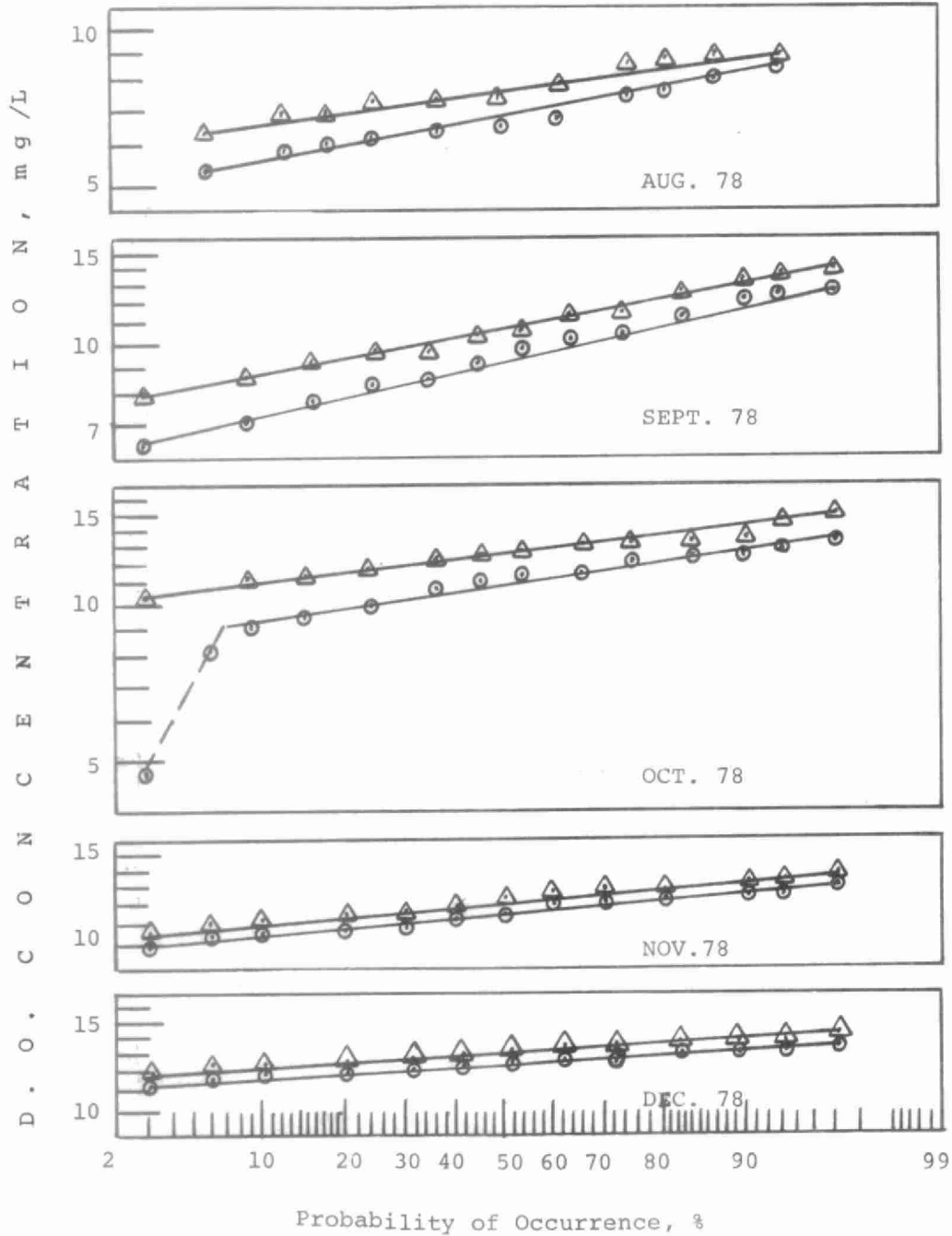


FIGURE 10 - CON'T.

#### 4.3 GRAND RIVER AT WOOLNER FLATS - STATION E6

Figure 11 shows the monthly probability distributions of minimum and mean daily DO at station E6 located on the main branch of the Grand River between Waterloo and Kitchener. No data were available for the period May-June 1977. The data points are seen to follow the log-normal distribution in a majority of the cases; however, in some of the plots, e.g., Oct. 77, there is a scatter of the data points in the lower probability range. DO levels were generally high, with the exception of July 1977 and June-September 1978.

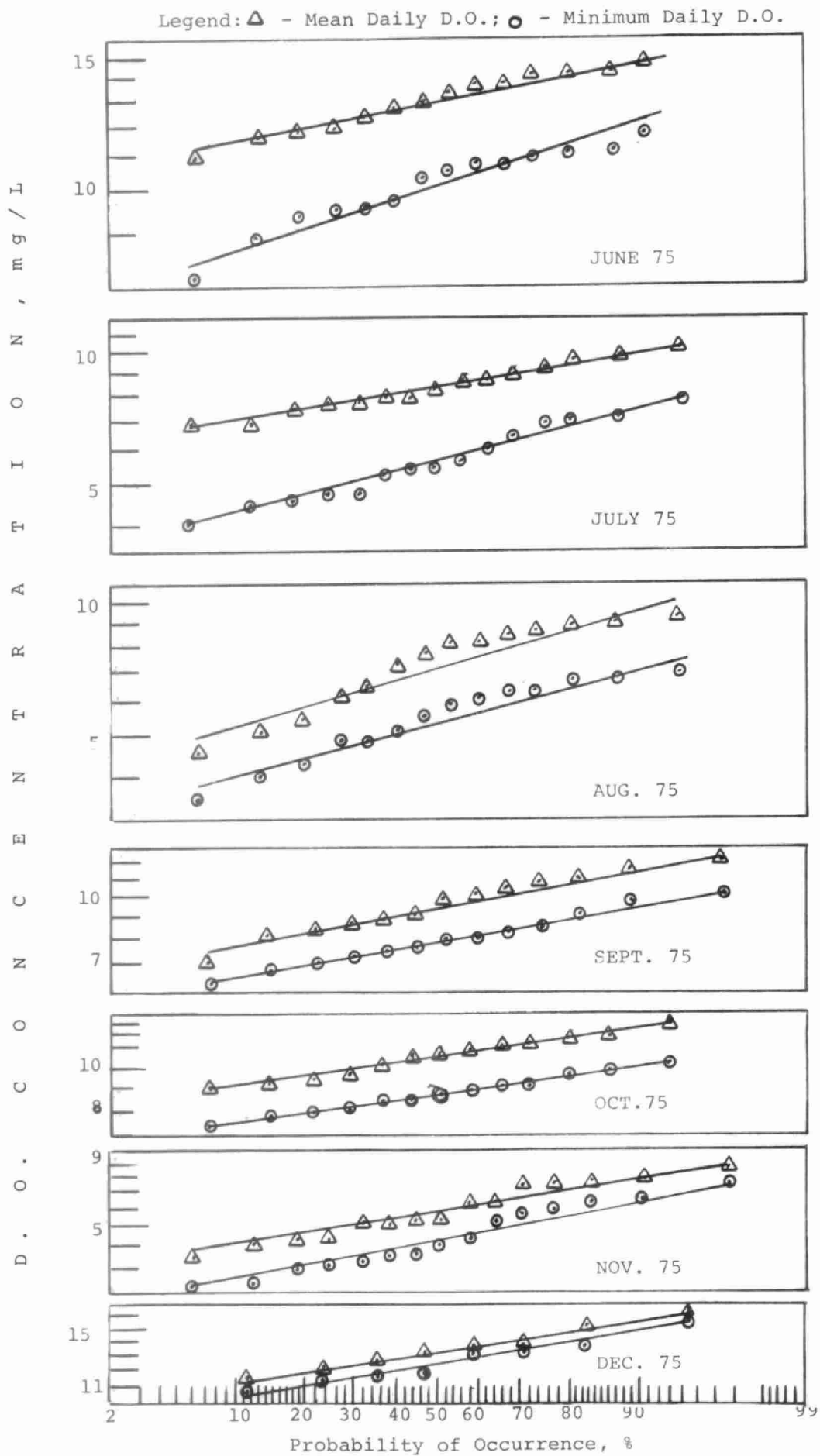


FIGURE 11 - PROBABILITY DISTRIBUTION OF D.O.  
LEVELS AT STATION E6 - WOOLNER FLATS

# WOOLNER FLATS 1976

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

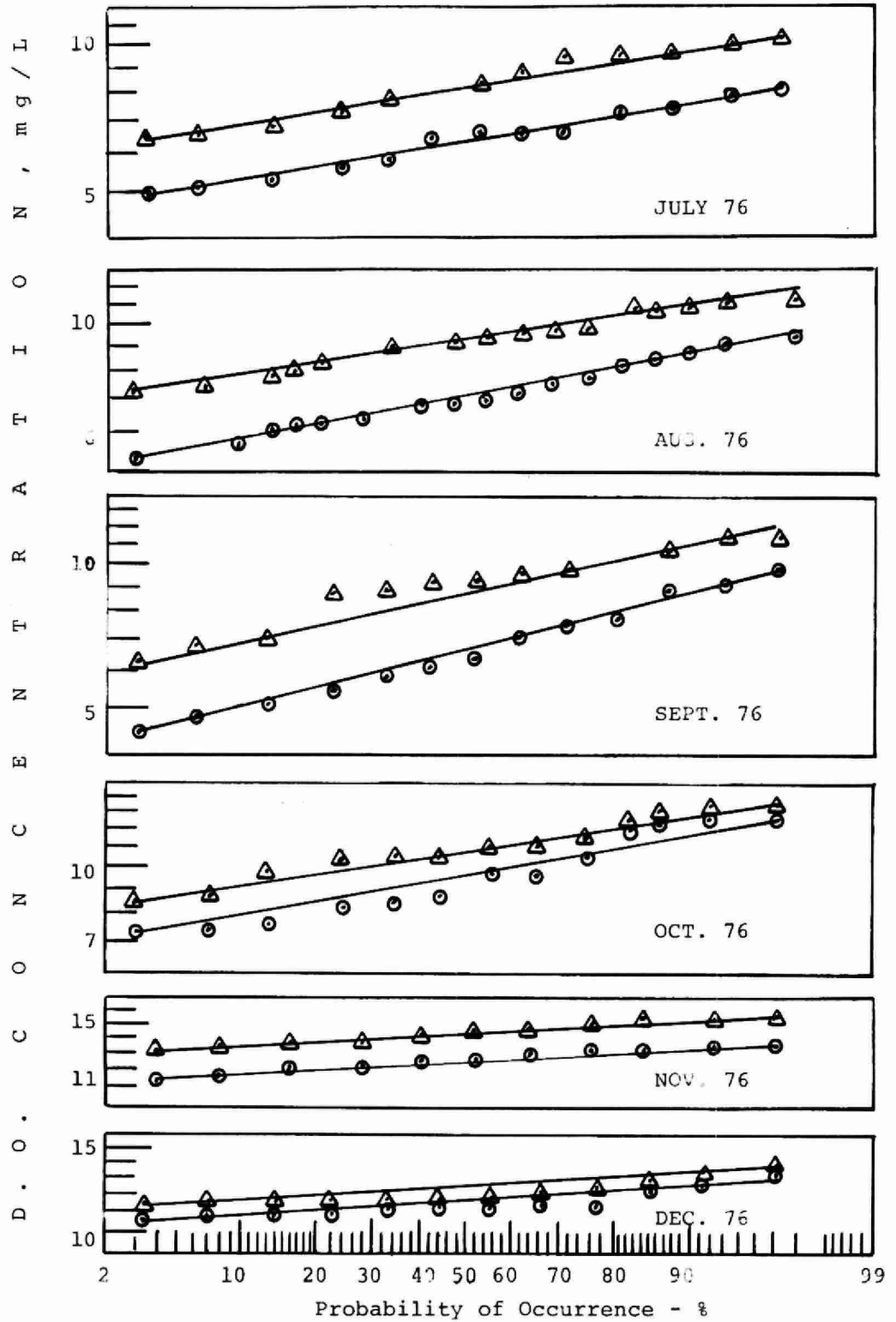


FIGURE 11 - CON'T.

WOOLNER FLATS 1977

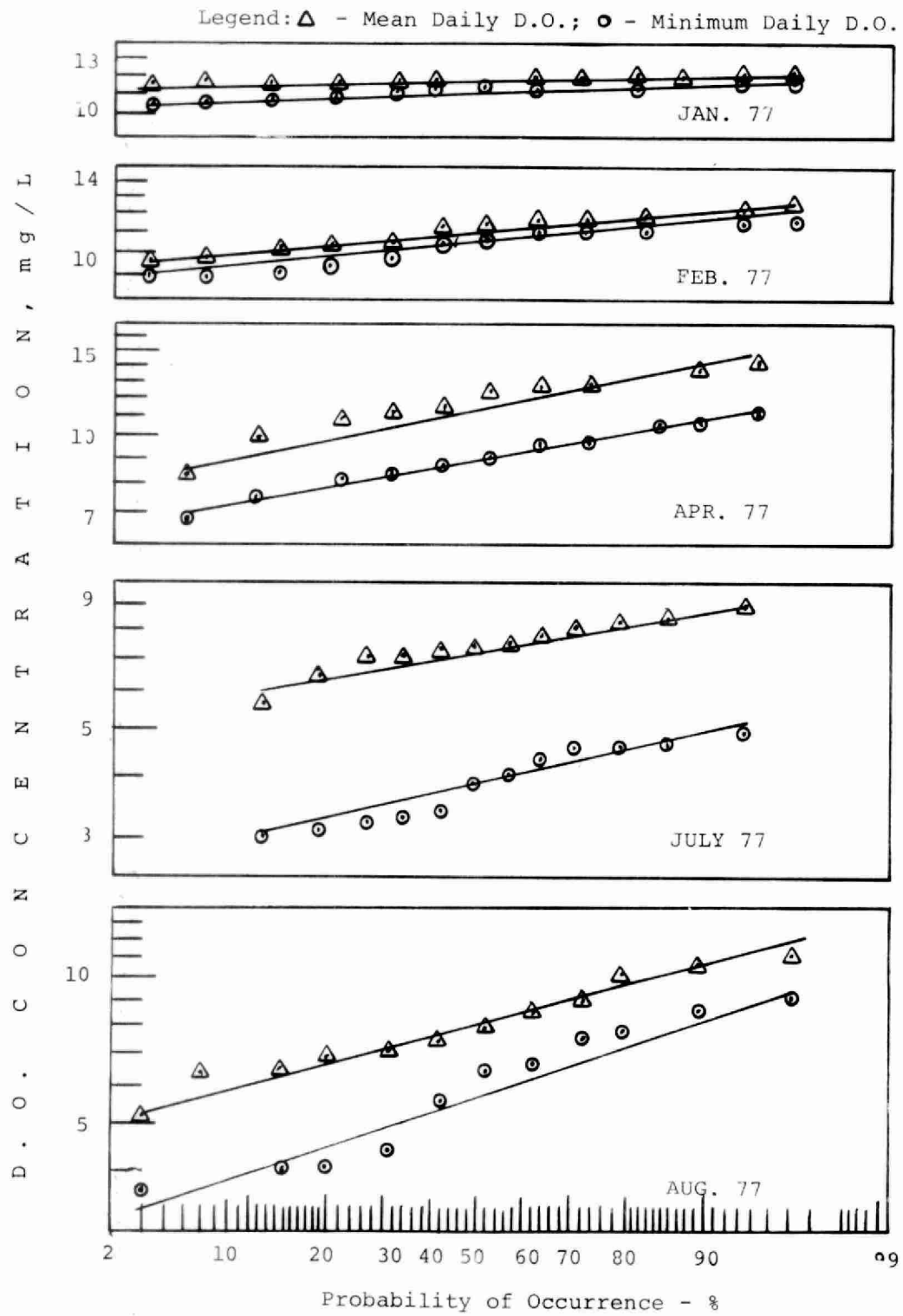


FIGURE 11 - CON'T.

# WOOLNER FLATS 1977

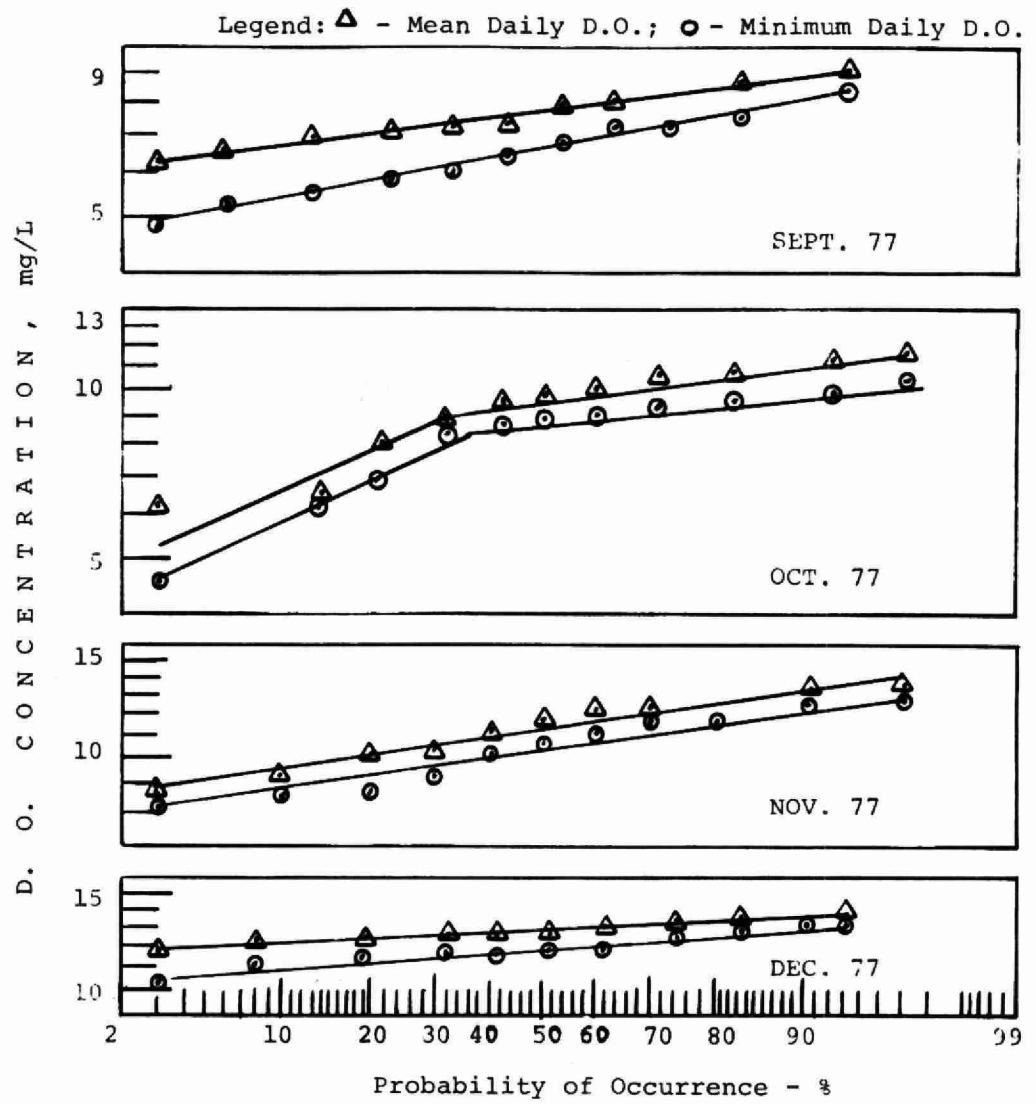


FIGURE 11 - CON'T.

WOOLNER FLATS 1978

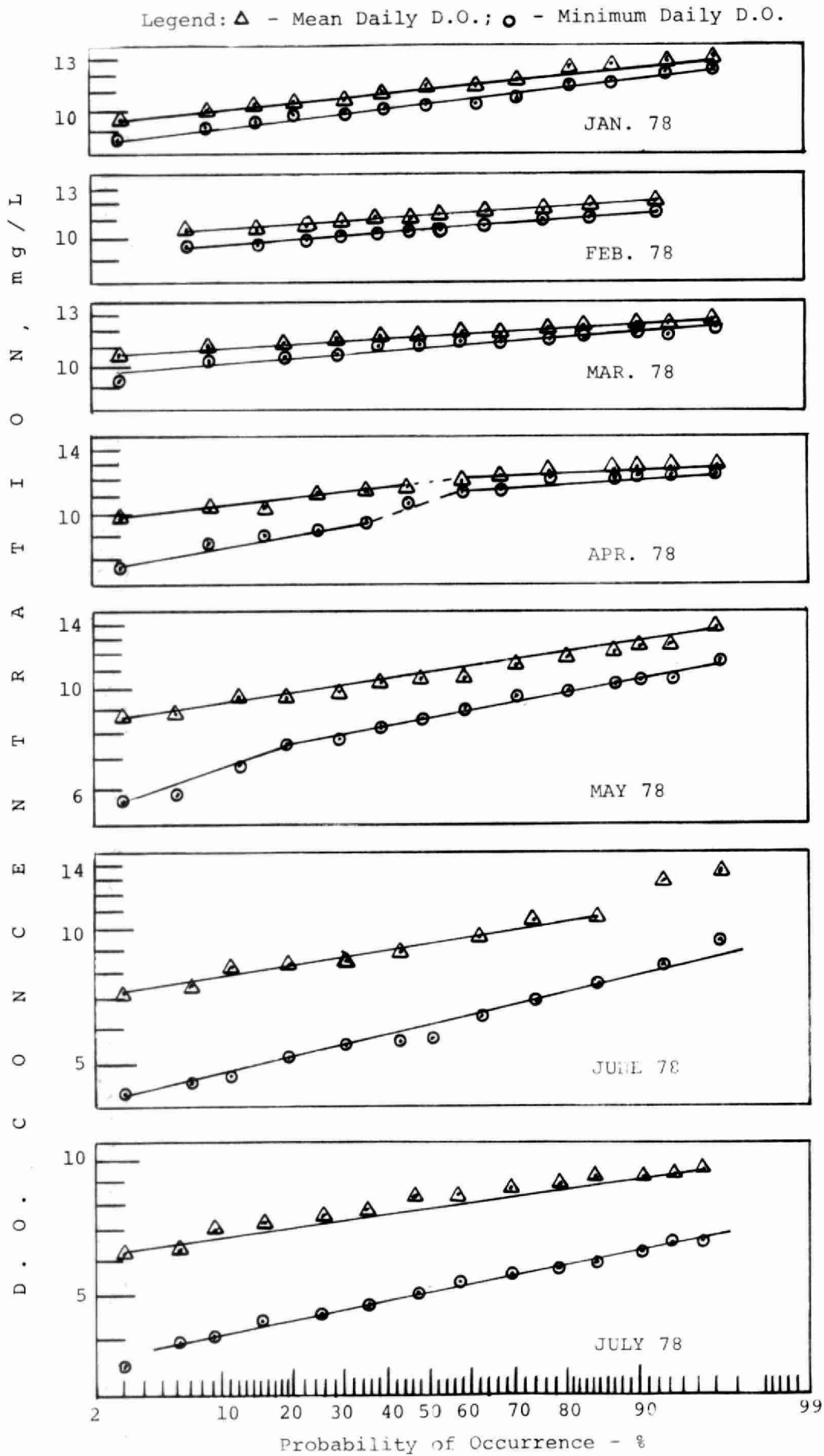


FIGURE 11 - CON'T.

WOOLNER FLATS 1978

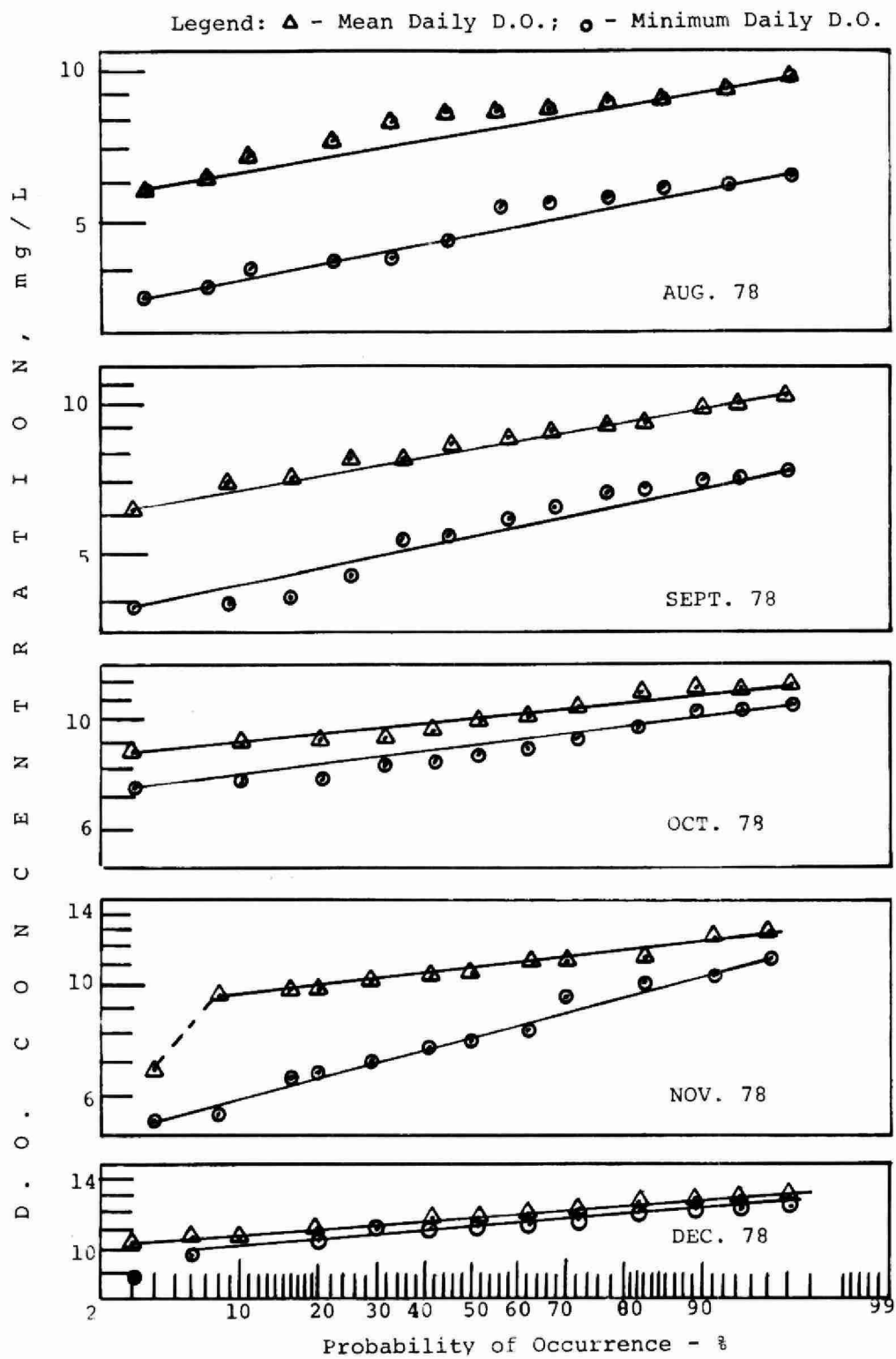


FIGURE 11 - CON'T.

#### 4.4 GRAND RIVER AT BLAIR - STATION N134

Data generated between November 1977 and October 1978 at the NERA monitoring station N134, located between Kitchener and the Grand-Speed confluence, have been included in the probability plots of mean and minimum daily DO levels, shown in Figure 12. From these plots, the DO levels are seen to be greater than 4 mg/L for most of the recording period. Only July and August show any periods of DO less than 5.0 mg/L.

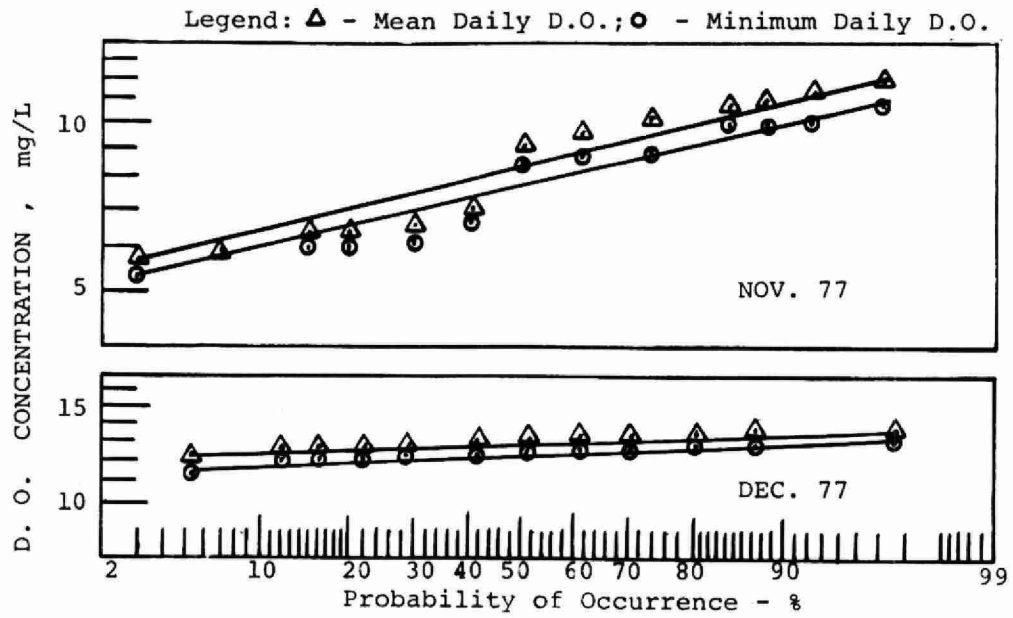


FIGURE 12 - PROBABILITY DISTRIBUTION OF D.O. LEVELS AT STATION N134 - GRAND RIVER AT BLAIR

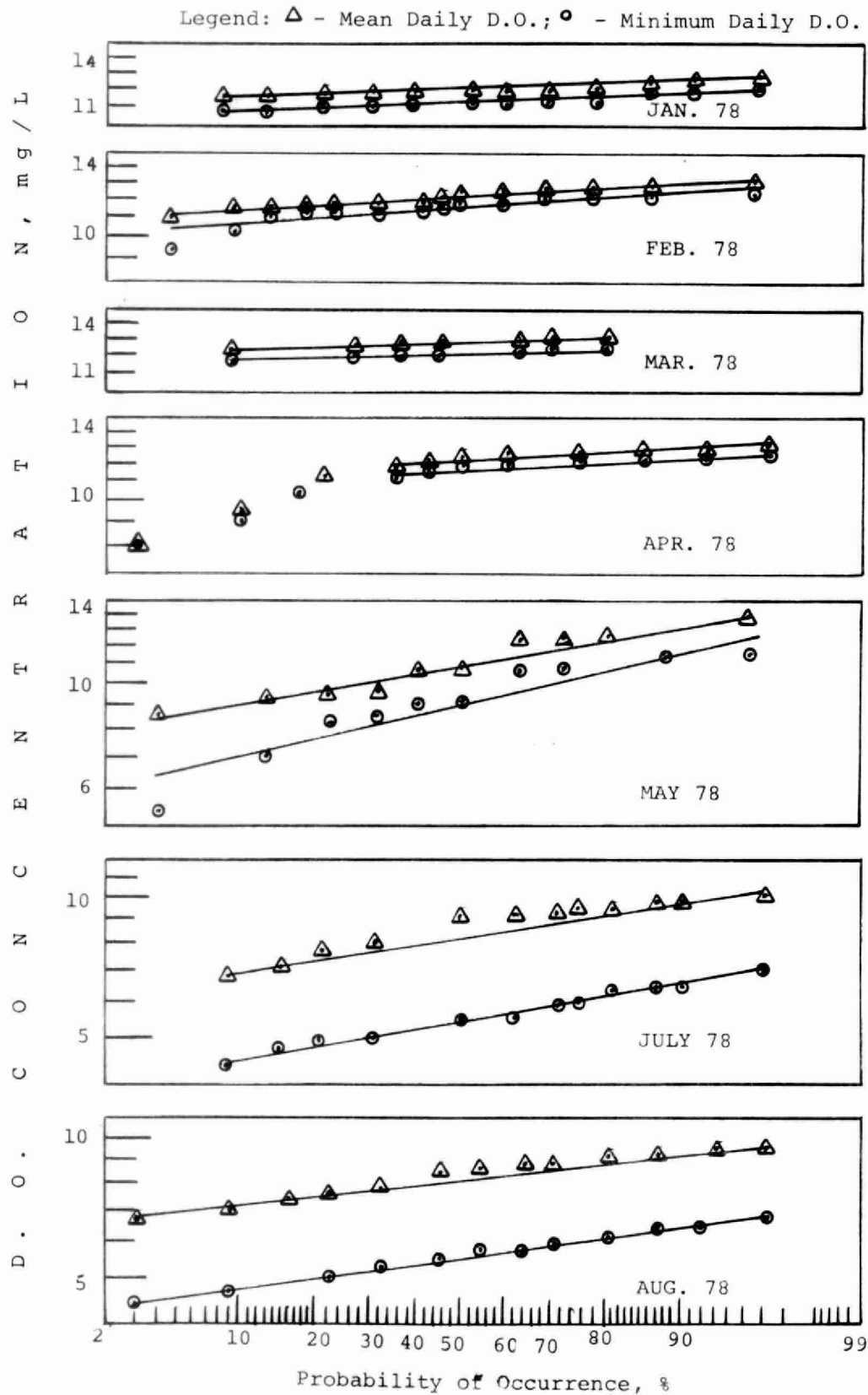


FIGURE 12 - CON'T.

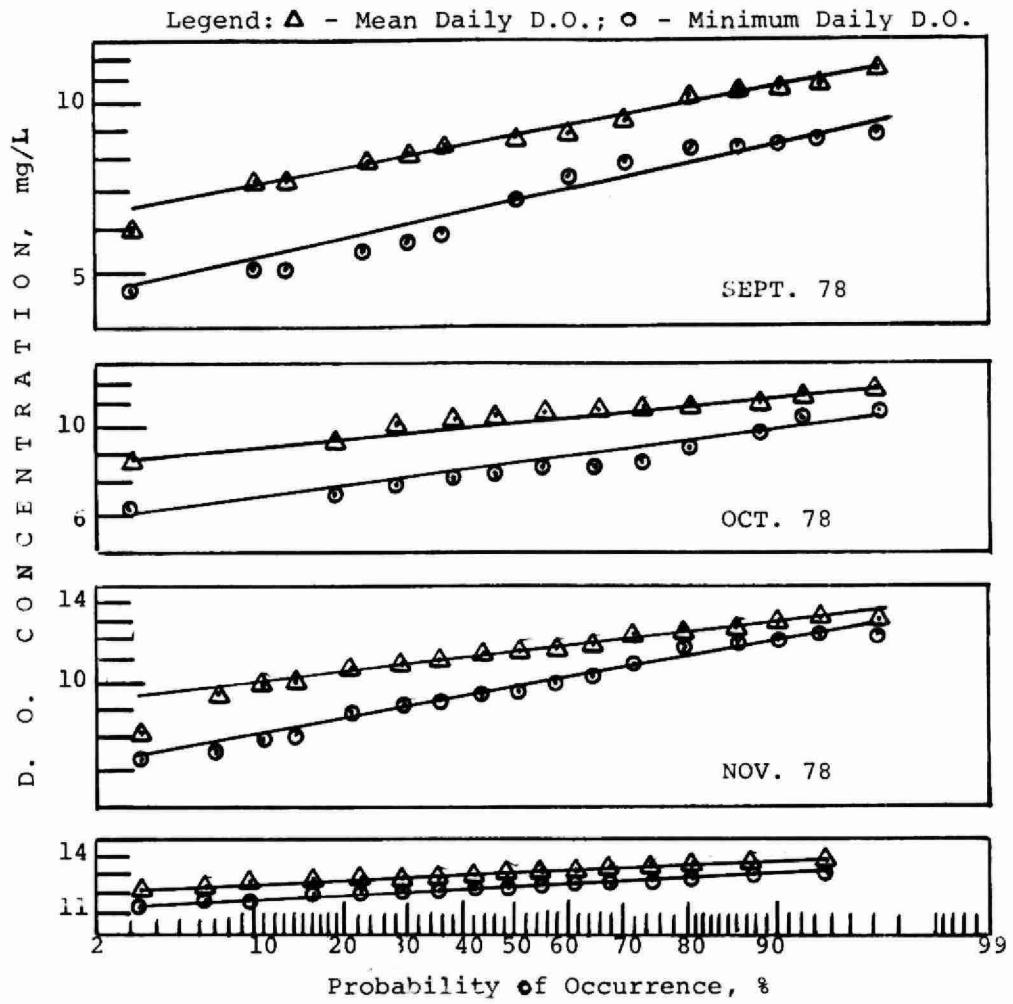


FIGURE 12 - CON'T.

#### 4.5        SPEED RIVER AT CANADIAN GYPSUM PLANT NEAR              GUELPH - STATION E3

The DO probability plots for station E3, the upstream station on the Speed River, are presented in Figure 13. The data show that the DO levels were over 4 mg/L during the entire period of record; the plots show, however, that up to 40% of the days had minimum DO levels below 5 mg/L in July and August of 1975, 1977 and 1978. Although this station is located at the downstream boundary of the City of Guelph, the DO levels are not likely to have been adversely affected by urban storm water runoff due to the very short travel times involved.

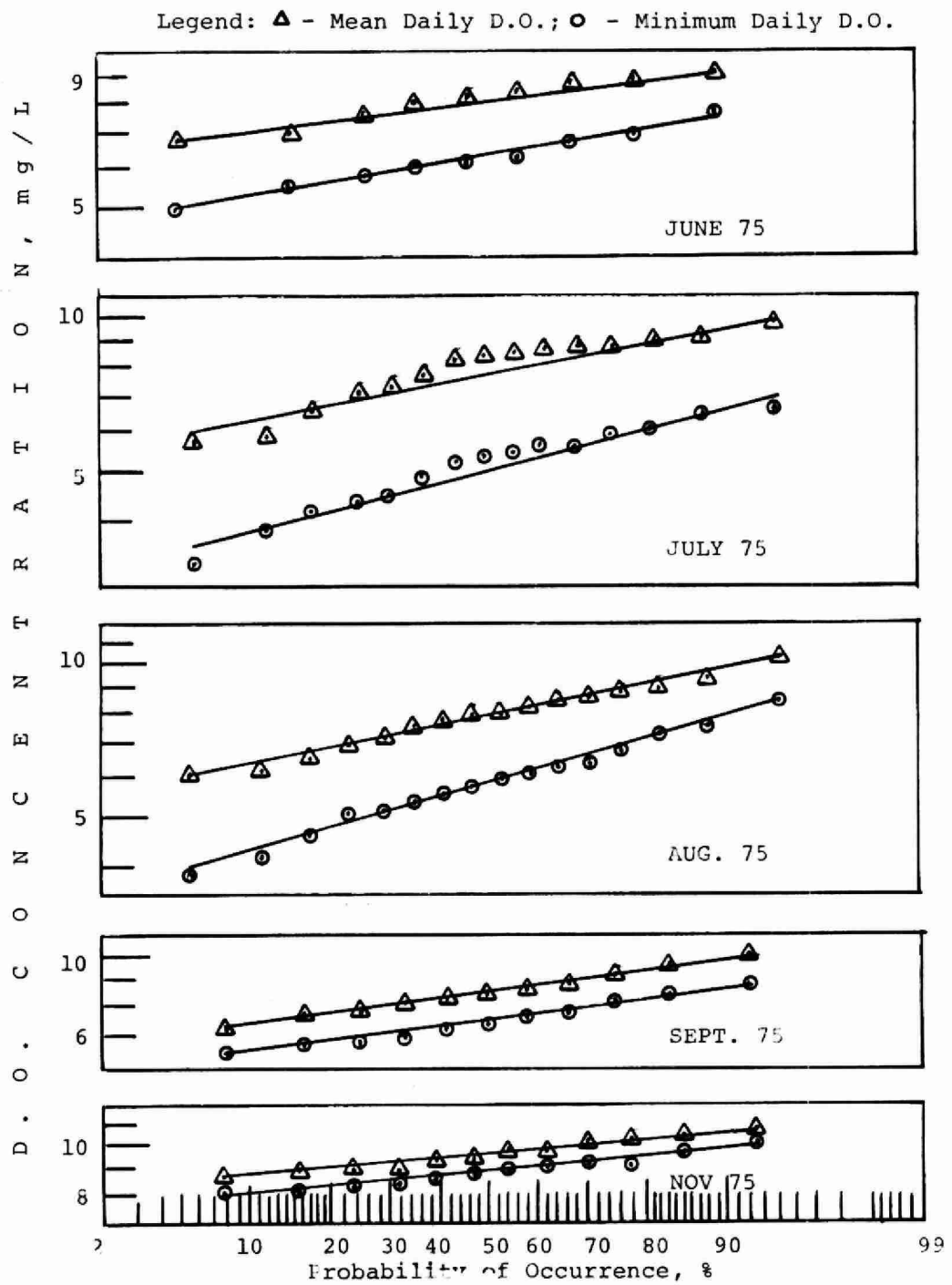


FIGURE 13 - PROBABILITY DISTRIBUTION OF D.O.  
LEVELS AT STATION E3 - SPEED RIVER  
AT CANADIAN GYPSUM IN GUELPH

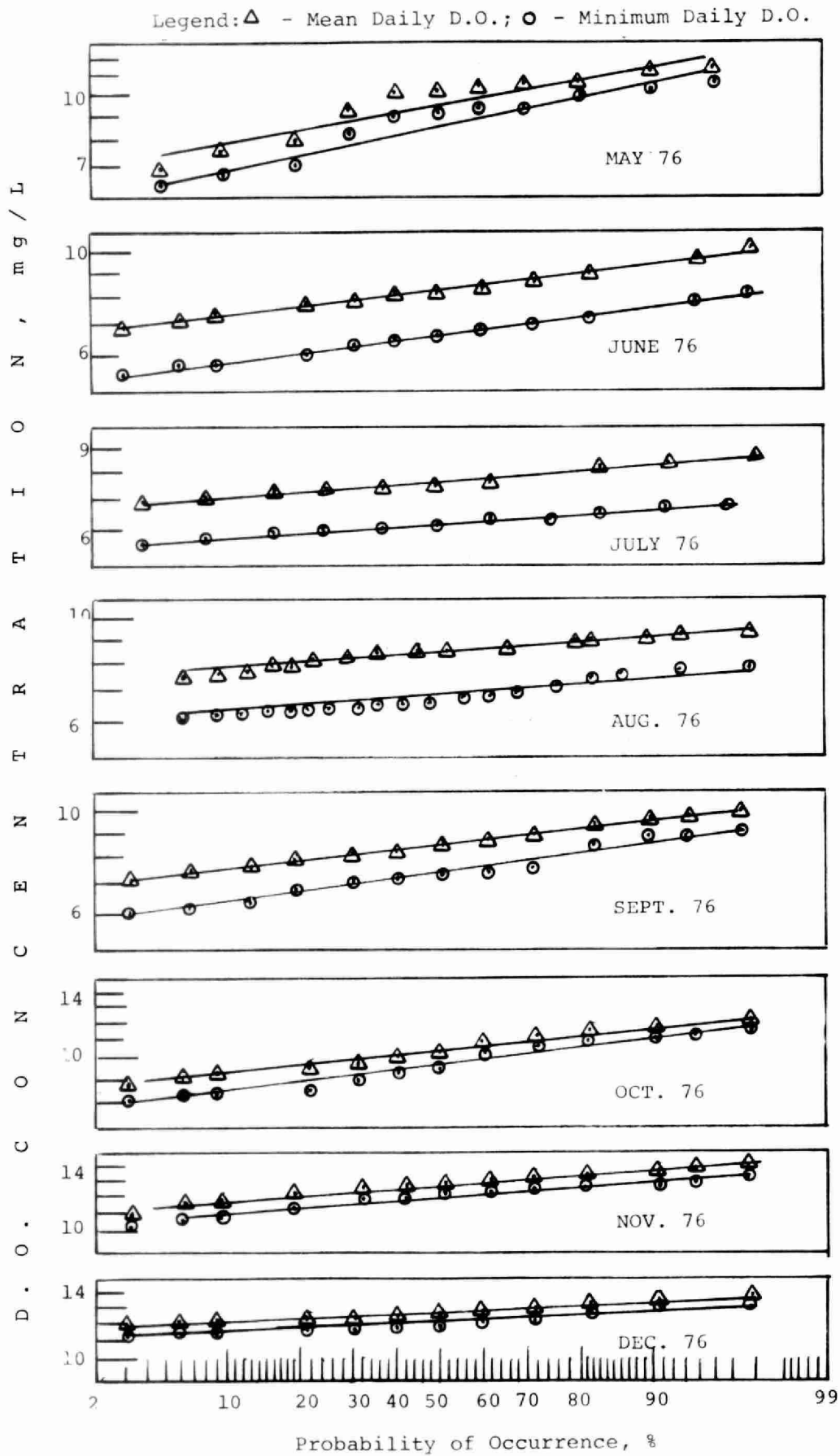


FIGURE 13 - CON'T.

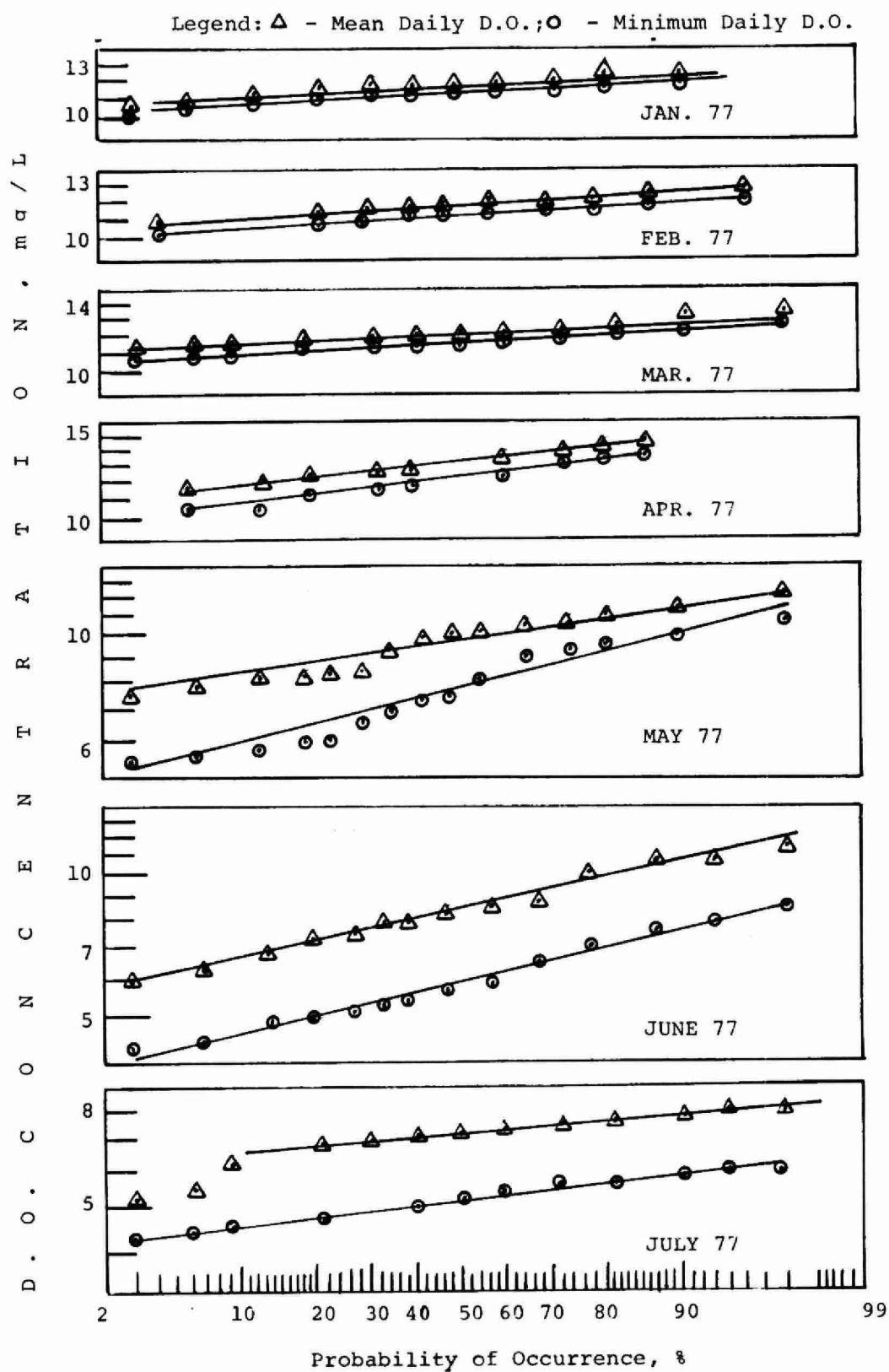


FIGURE 13 - CON'T.

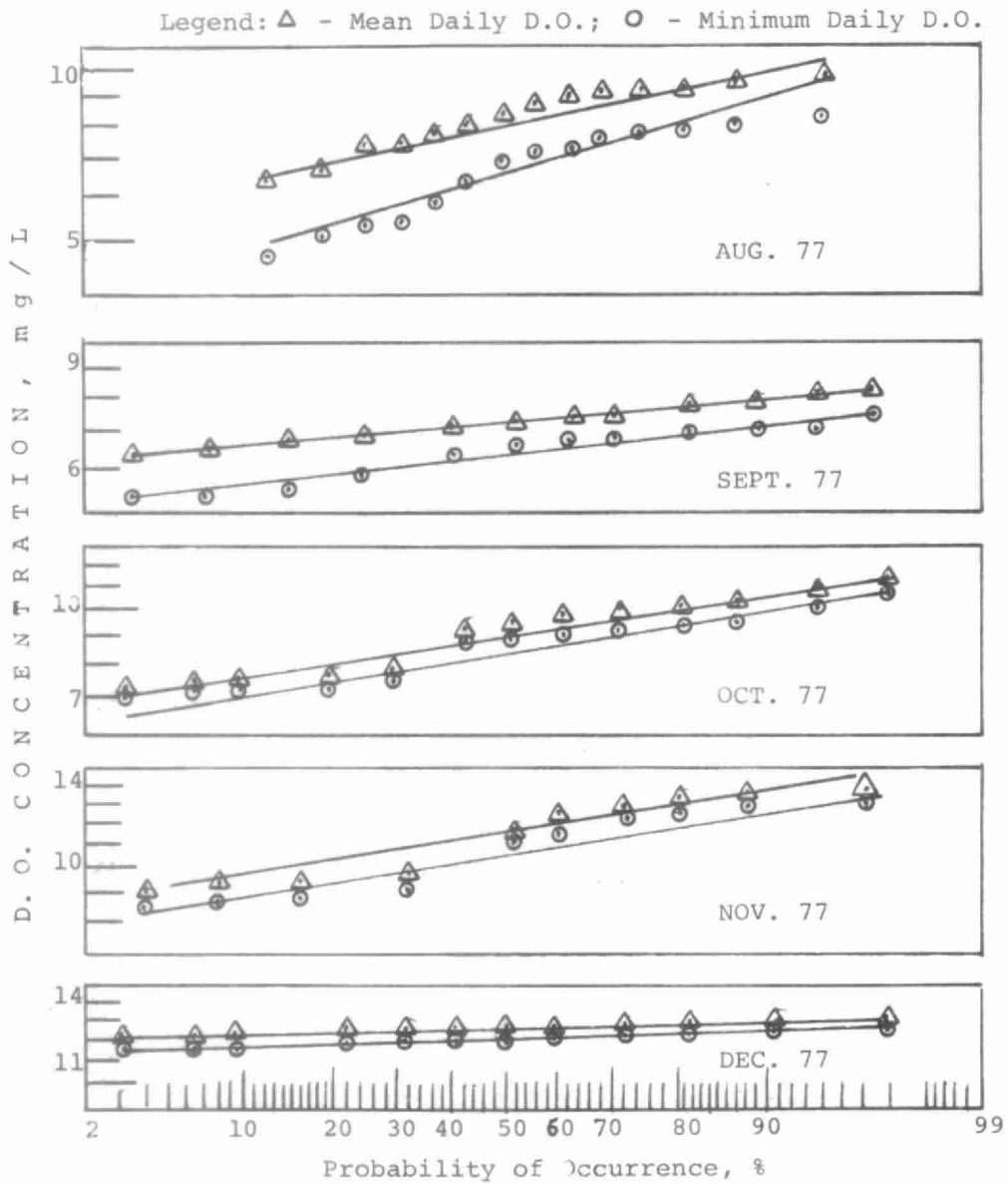


FIGURE 13 - CON'T.

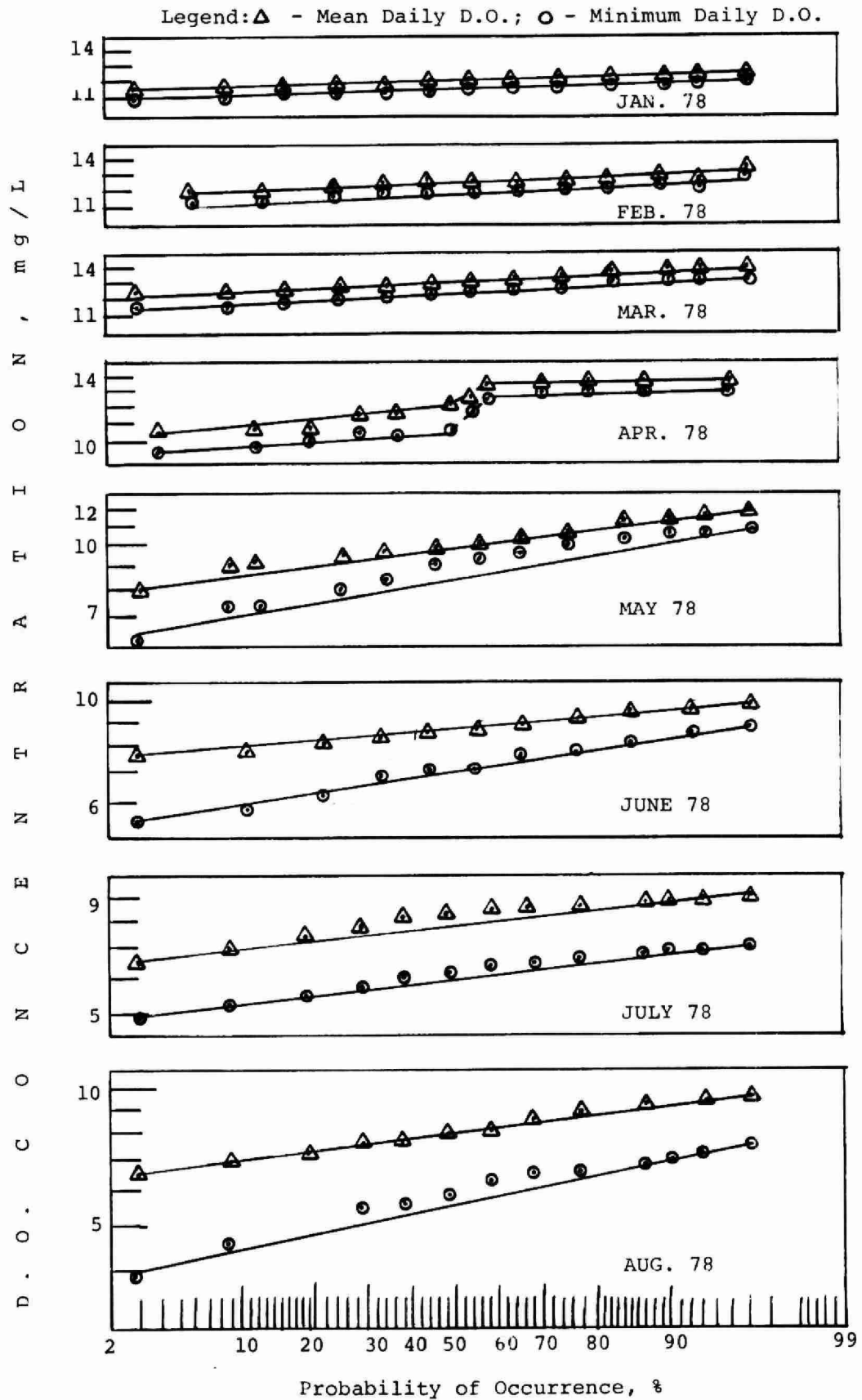


FIGURE 13 - CON'T.

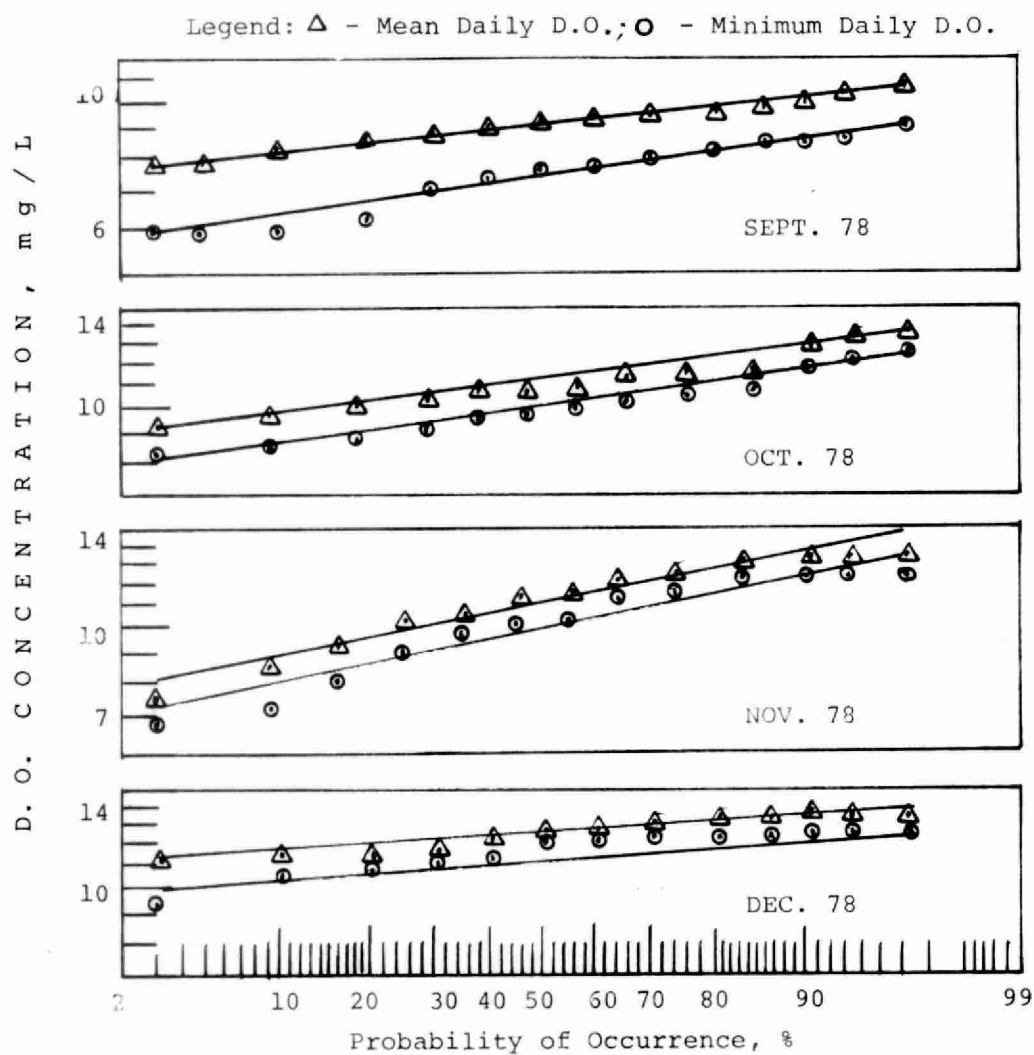


FIGURE 13- CON'T.

#### 4.6 SPEED RIVER AT GLEN CHRISTIE - STATION N135

The DO probability plots at the NERA station N135, located below the Guelph water pollution control plant (WPCP), are shown in Figure 14 for the period June 1976-December 1978, with the exception of February and March 1977. The minimum DO plots contrast with those of other stations in that the lines of best fit are generally steeper than those for the mean DO plots. This corresponds to a greater variation of within-day DO range than for other stations. Generally, during the period May-November of each year, the DO levels are seen to be very low, being frequently lower than 4 mg/L. The daily mean DO plots show less than 5 mg/L for up to 60% of the time during several months.

The break in the plot of September 1976 data is probably due to a washout of algal biomass resulting from a large increase in flow rate in mid-month. Plots for several other months illustrate similar deviations from the linear form indicating a sensitivity of DO at this station to physical changes in the river.

# SPEED RIVER 1976

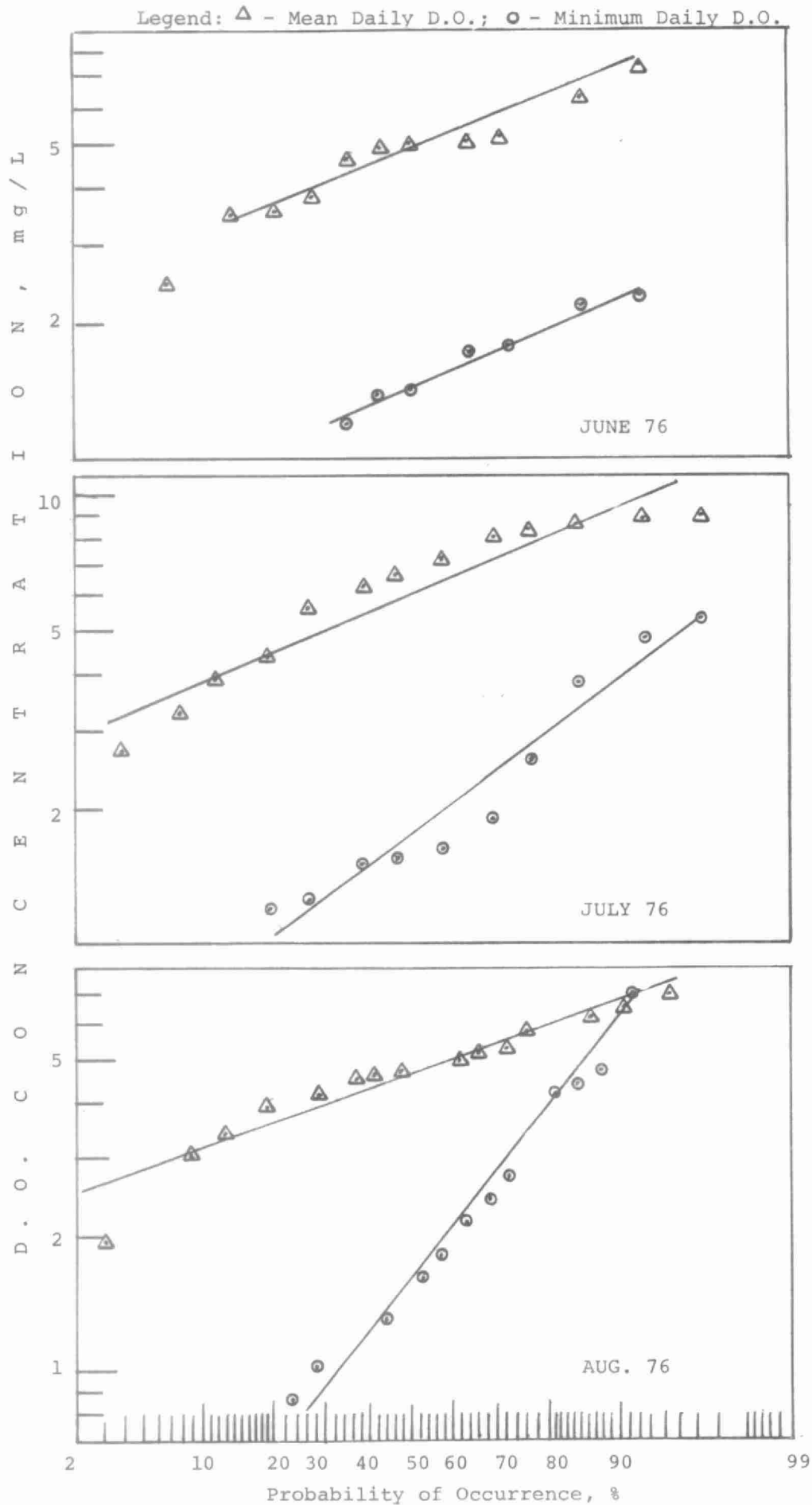


FIGURE 14 - PROBABILITY DISTRIBUTION OF D.O.  
LEVELS AT STATION N135 - SPEED RIVER  
-60-

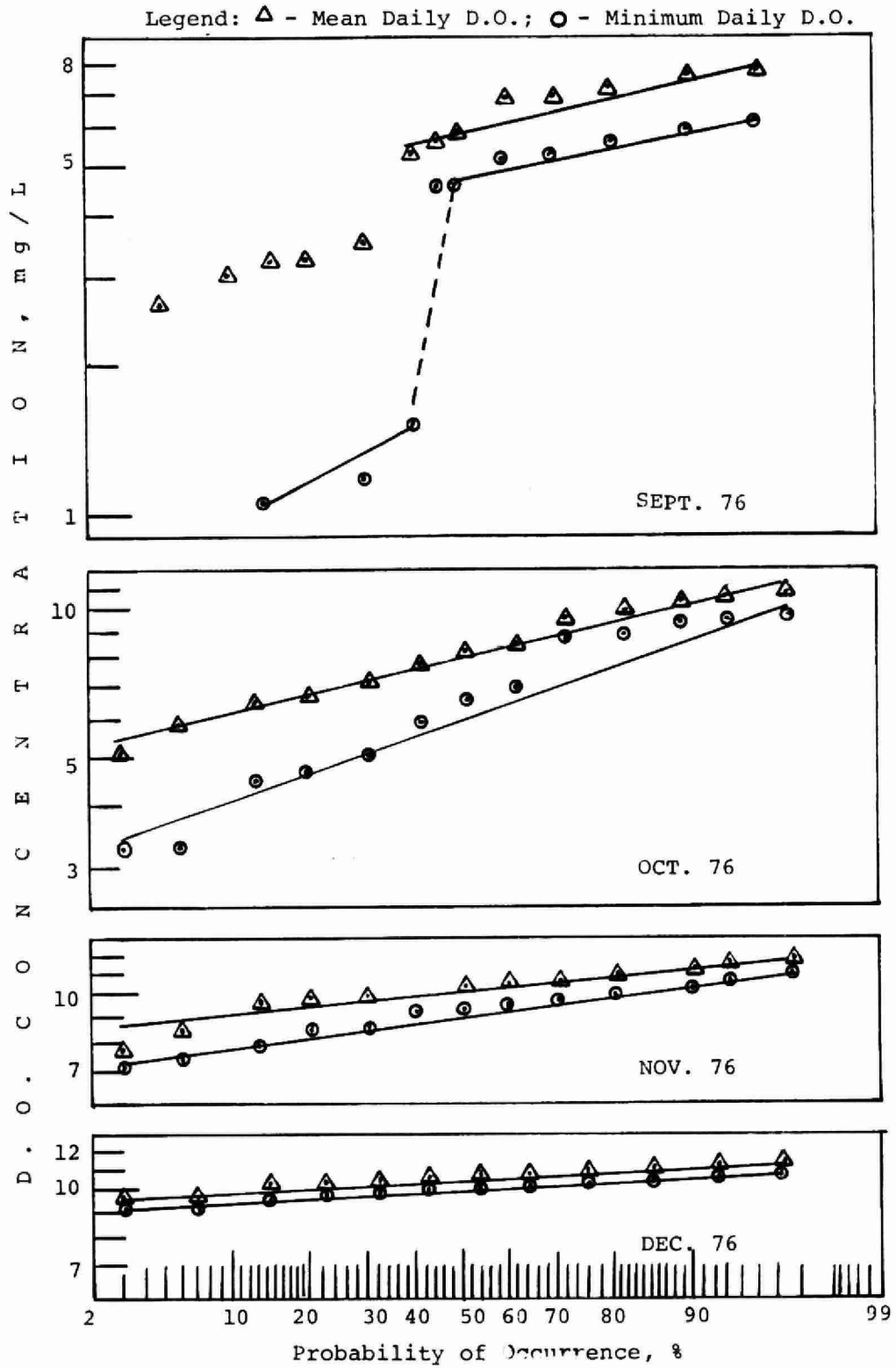


FIGURE 14 - CON'T.

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

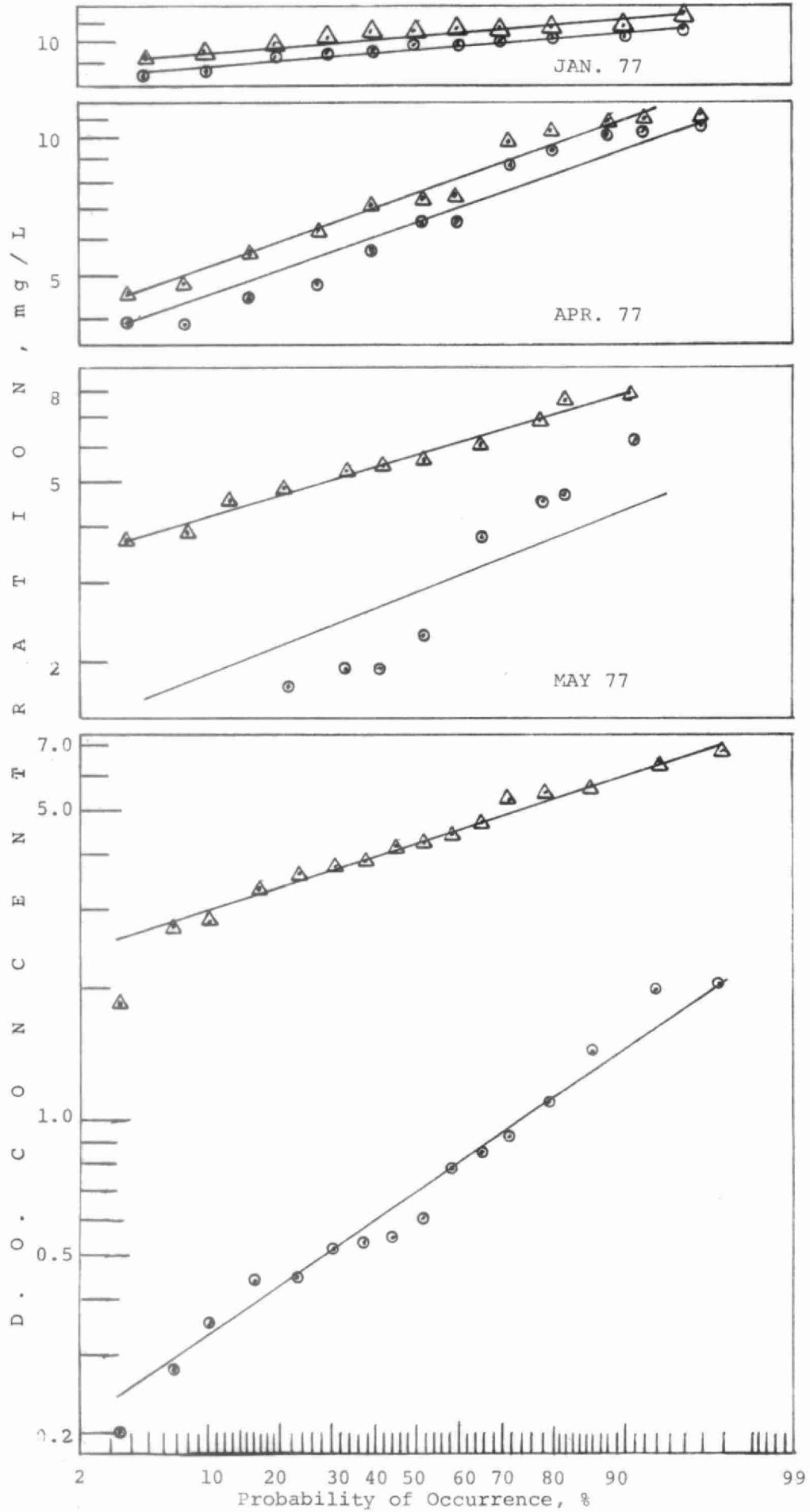


FIGURE 14 - CON'T.

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

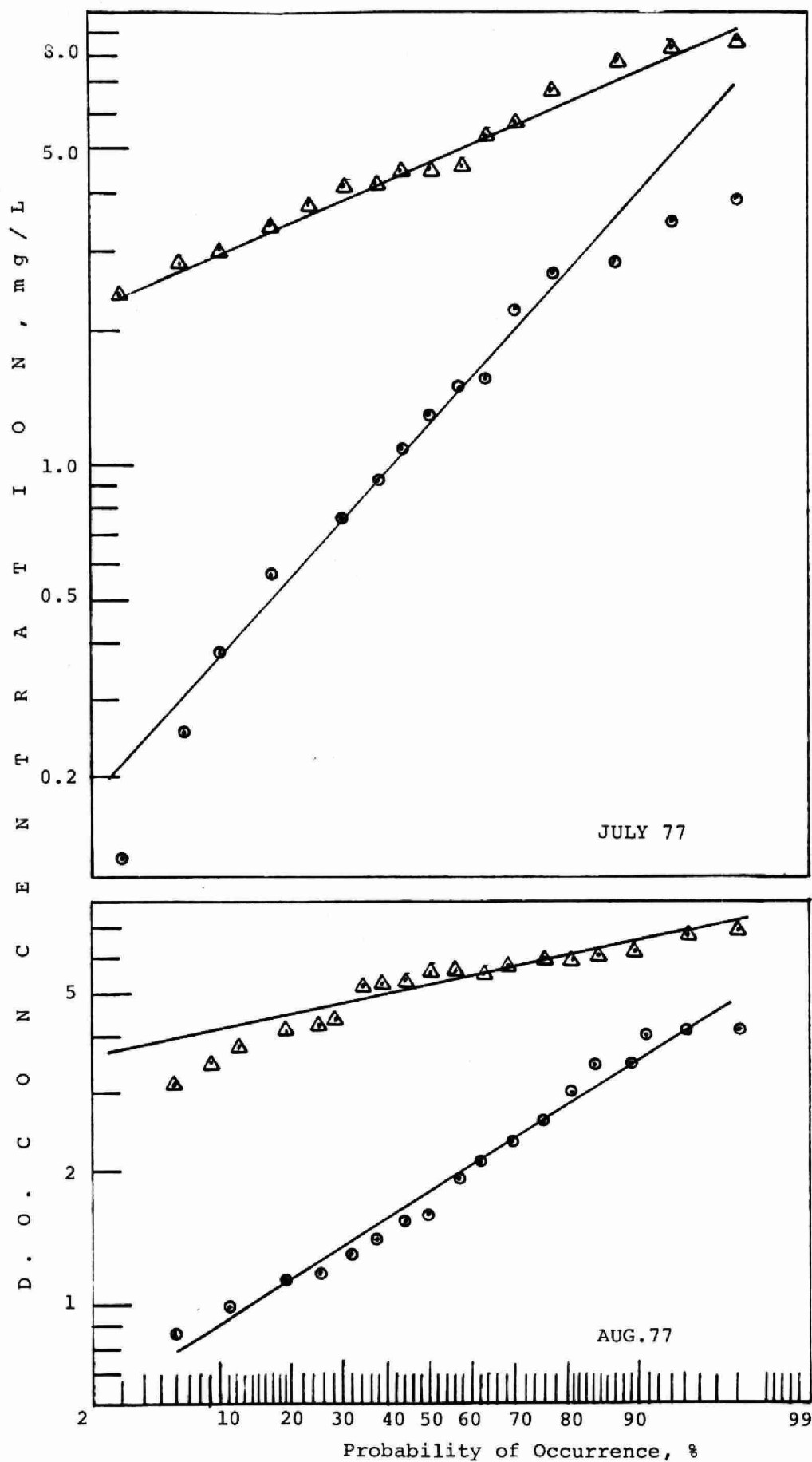


FIGURE 14 - CON'T.

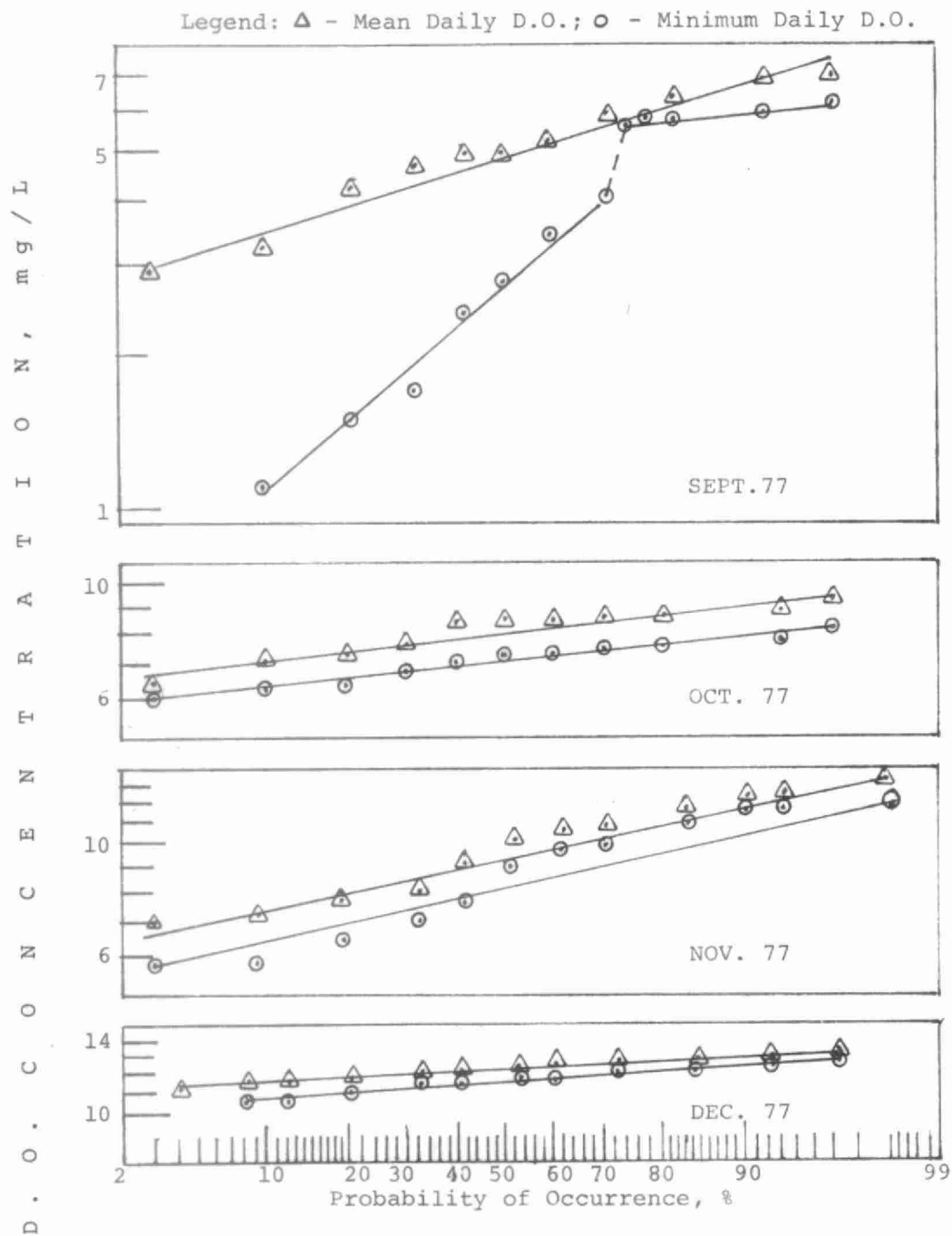


FIGURE 14 - CON'T.

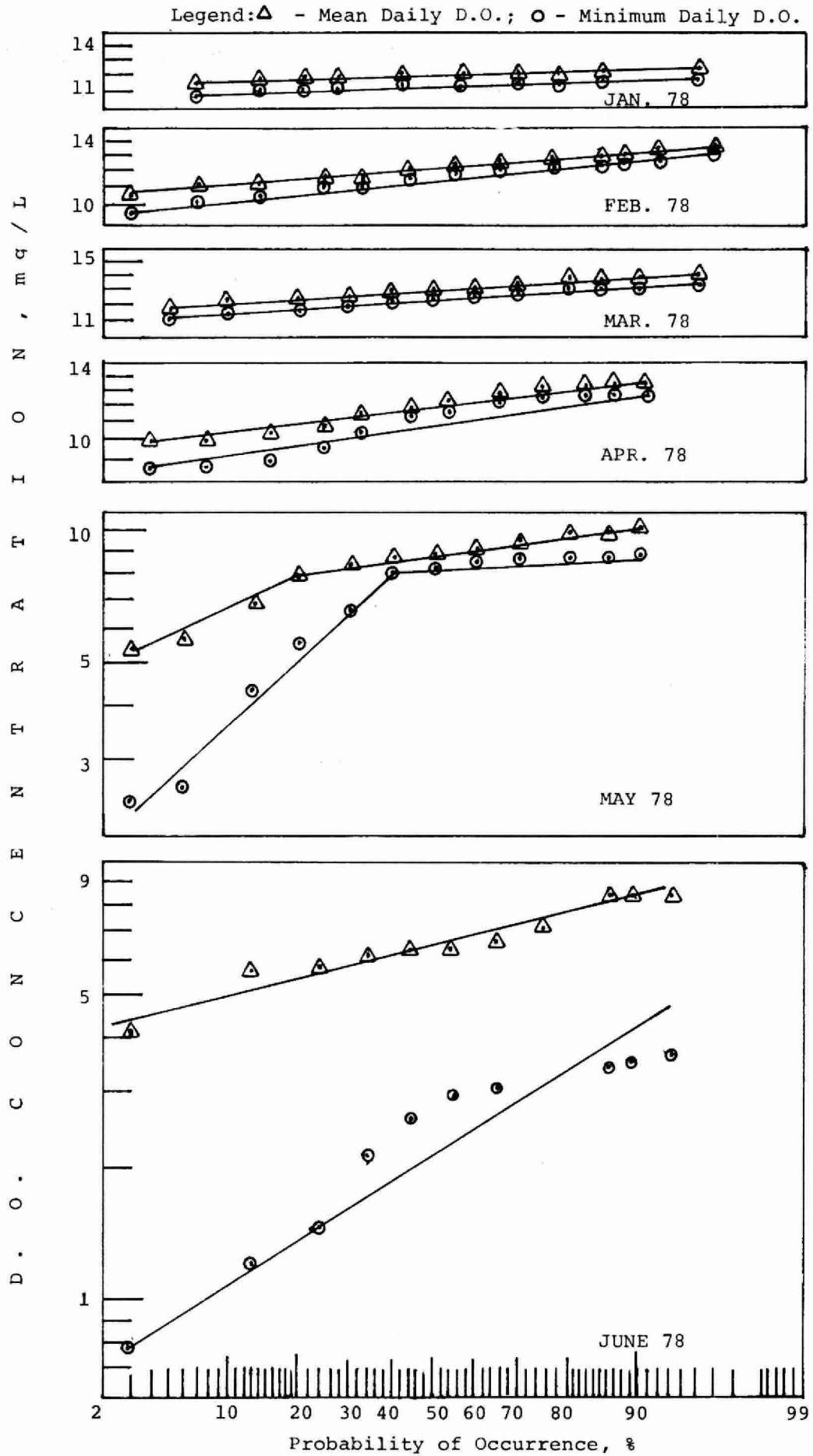


FIGURE 14 - CON'T.

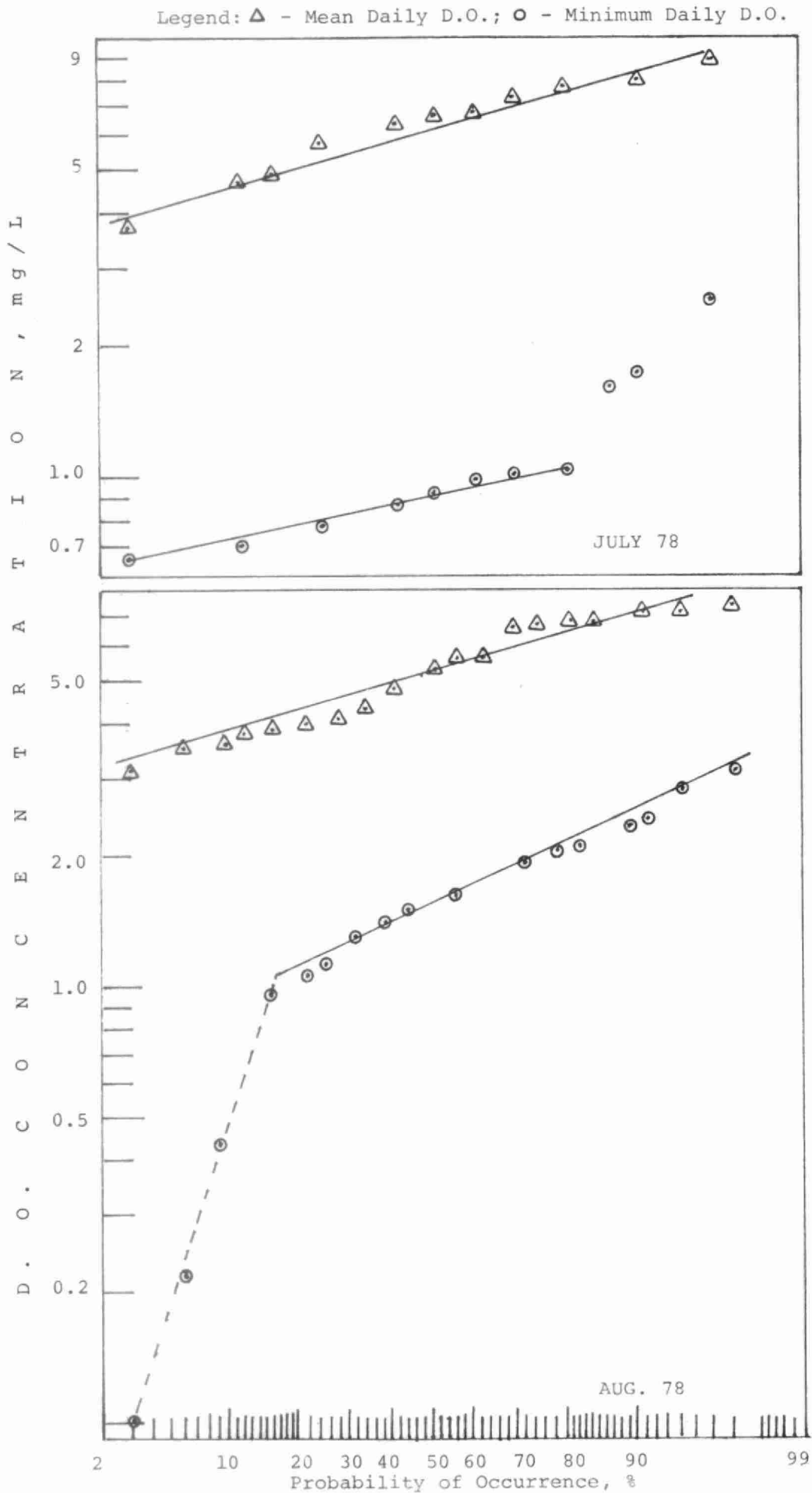


FIGURE 14 - CON'T.

Legend:  $\Delta$  - Mean Daily D.O.;  $\circ$  - Minimum Daily D.O.

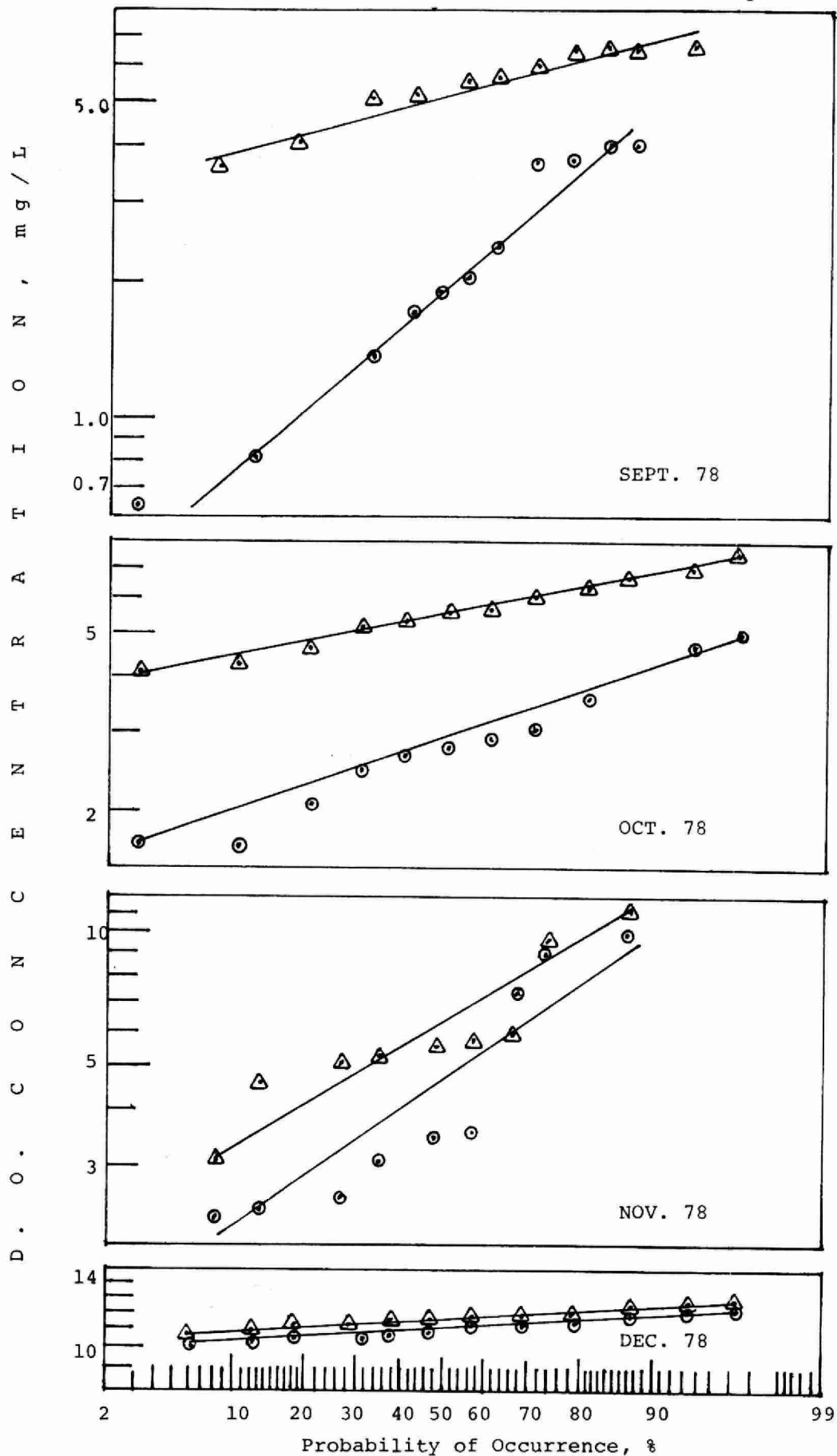


FIGURE 14 - CON'T

#### 4.7 SPEED RIVER AT PRESTON - STATION E5

Figure 15 shows the probability distribution plots of the mean and minimum DO levels at station E5, located near the mouth of Speed River, for the period May 1975 - December 1978. Generally, the data follow the log-normal distribution. From the plots, it can be seen that the DO levels were very low during May-September, minimum daily DO being lower than 4 mg/L on up to 60% of the days in some months. Data was available for June through August 1978, but has been omitted from the plots because of a probe malfunction during this period.

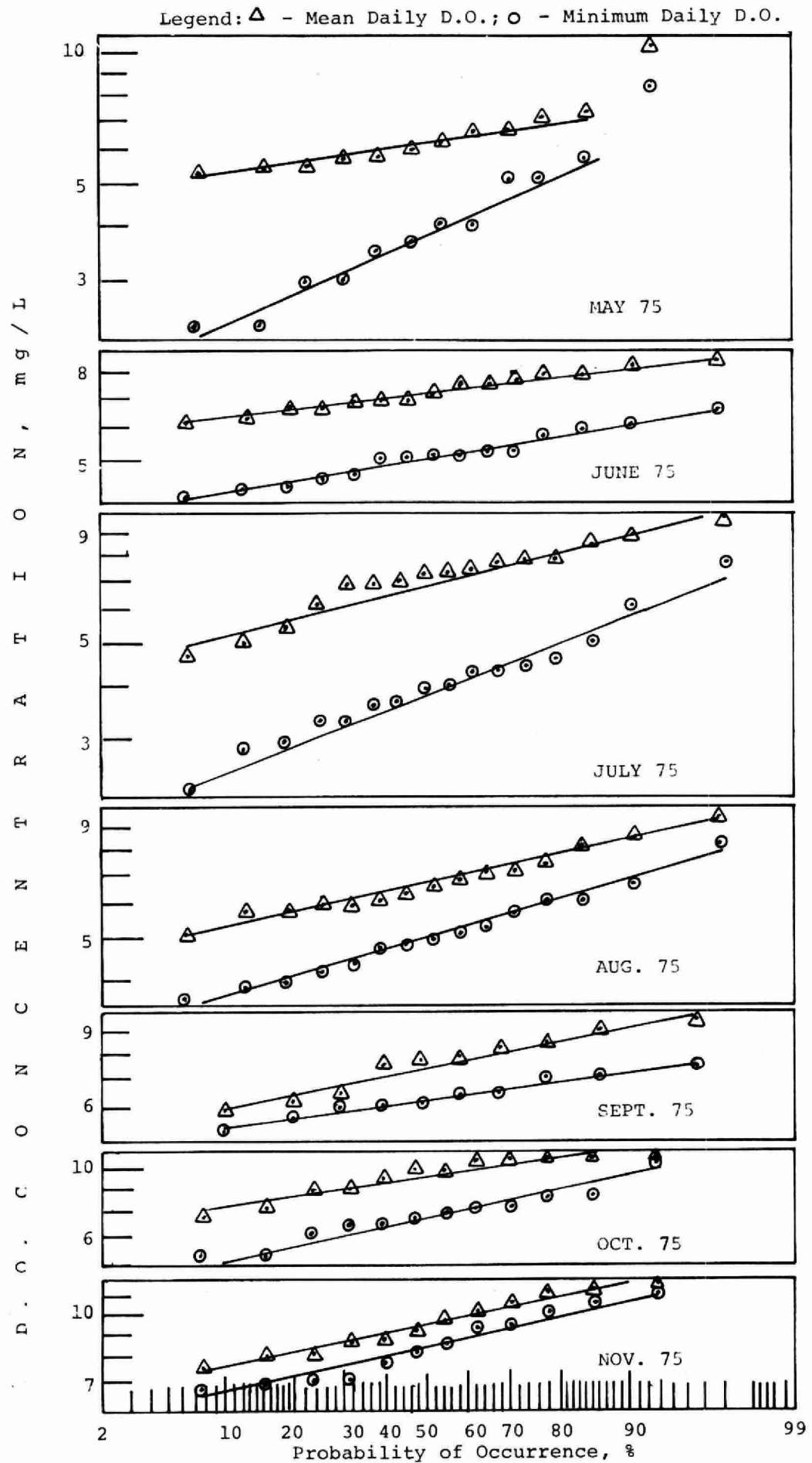


FIGURE 15 - PROBABILITY DISTRIBUTION OF D.O.

LEVELS AT STATION E5 - PRESTON

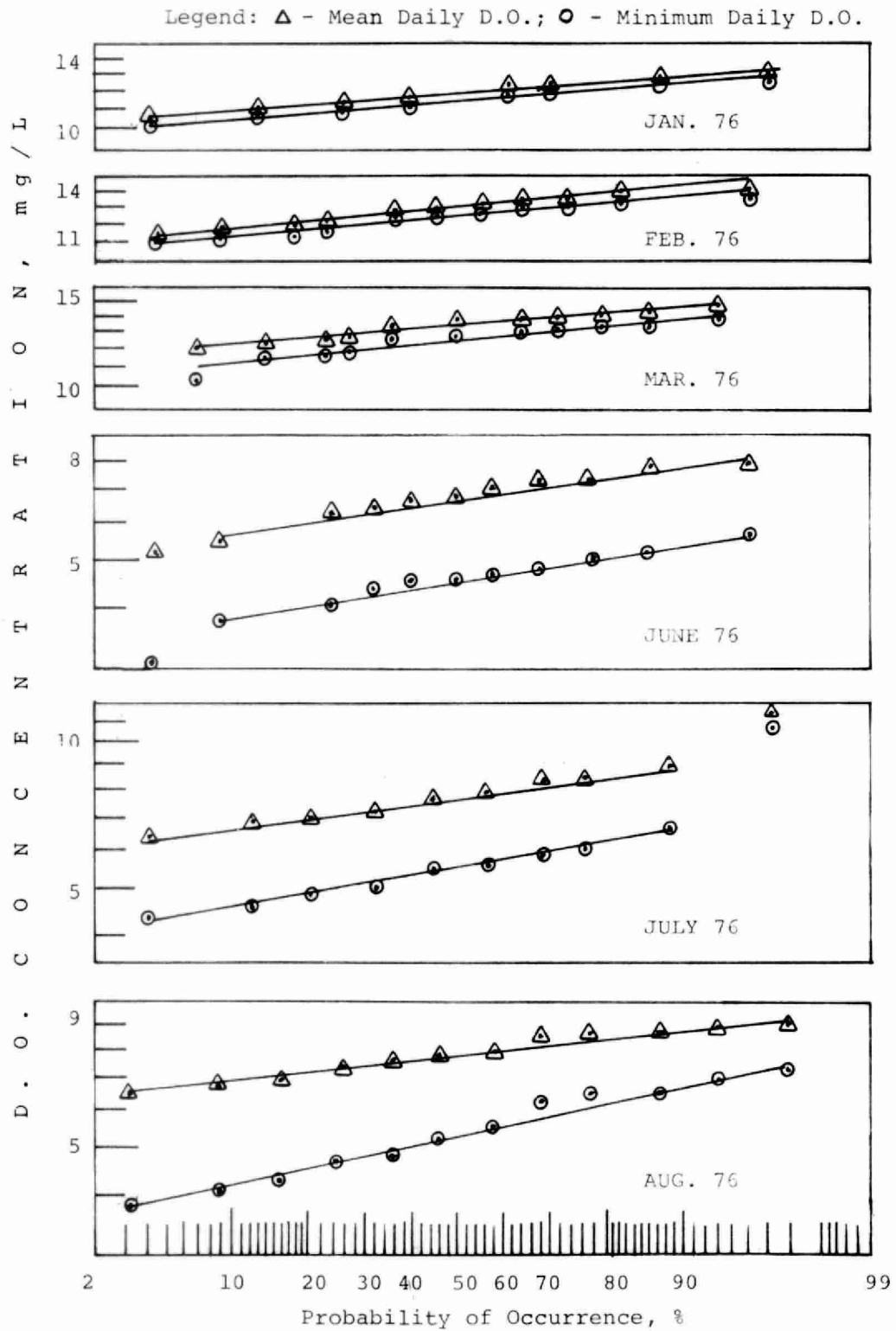


FIGURE 15 - CON'T.

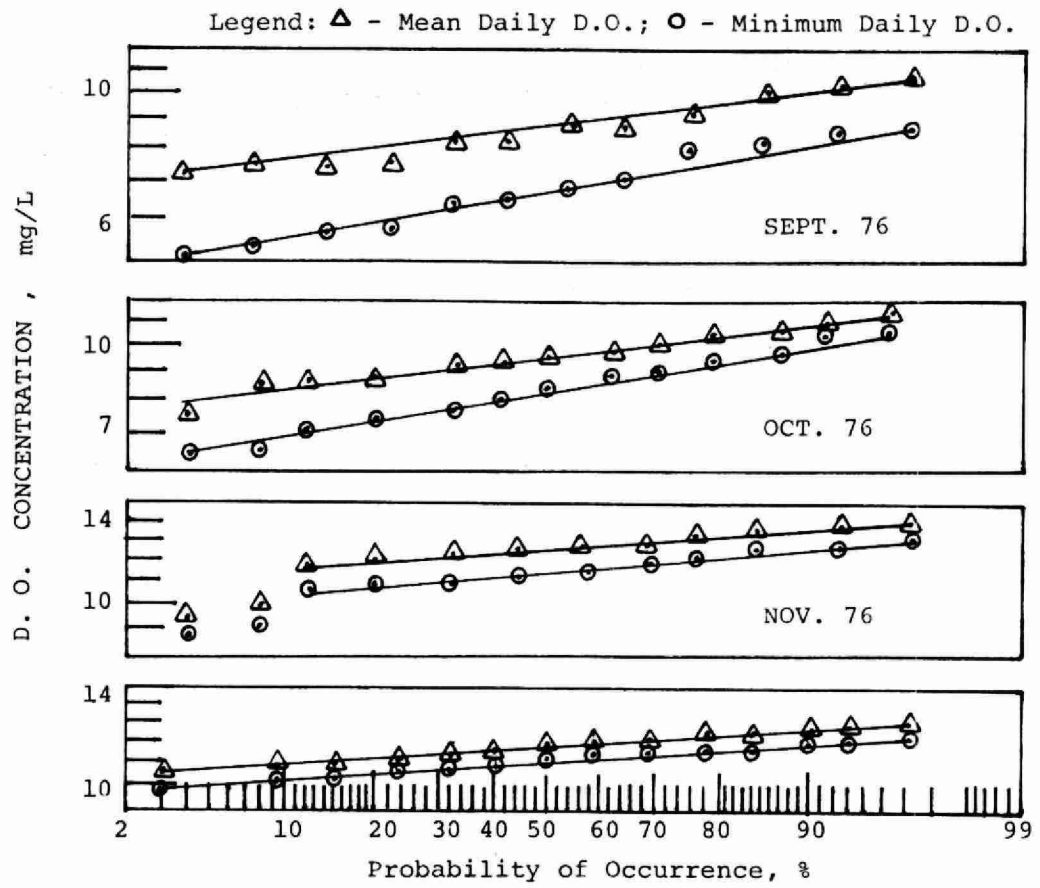


FIGURE 15 - CON'T.

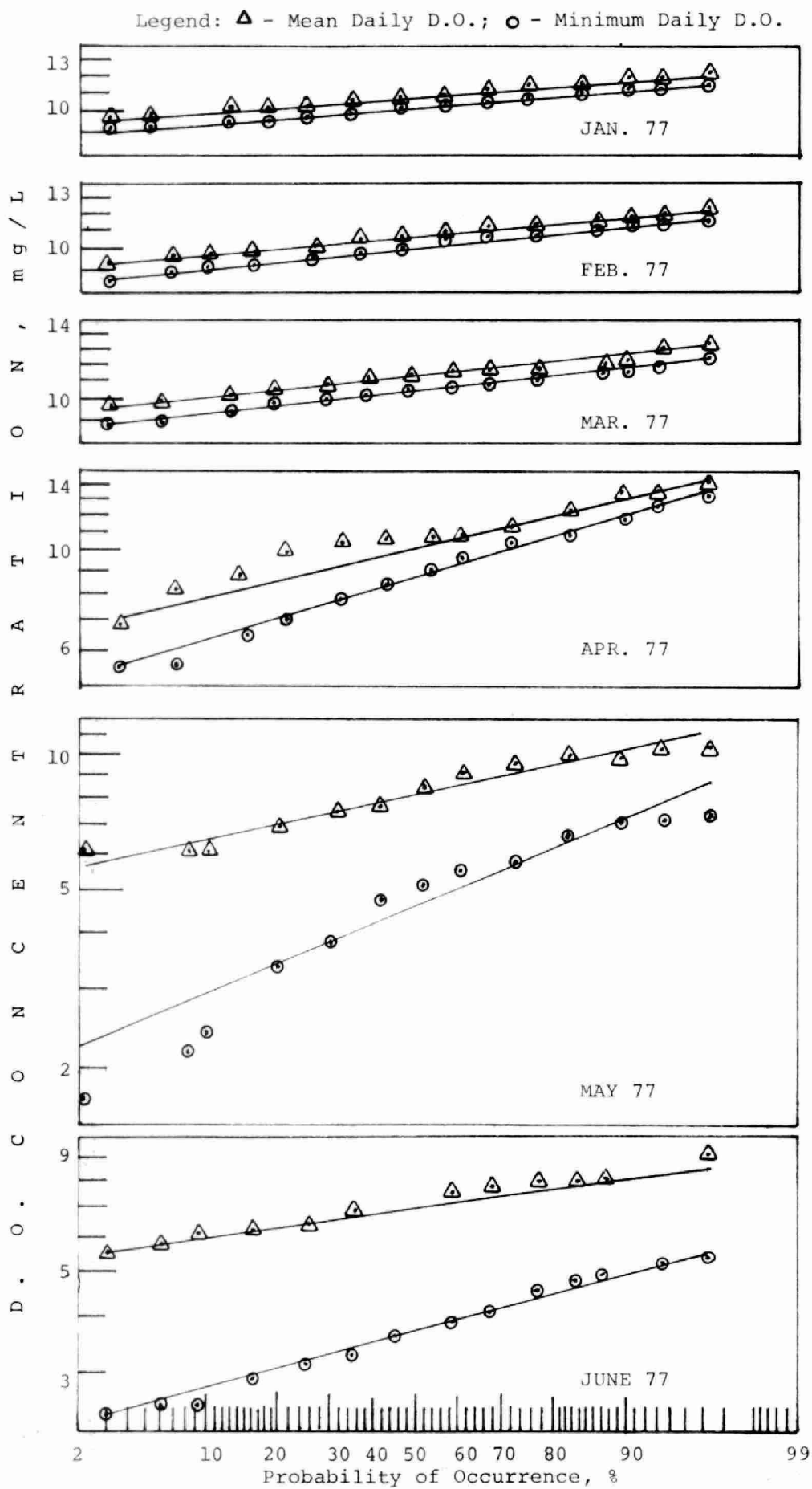


FIGURE 15 - CON'T.

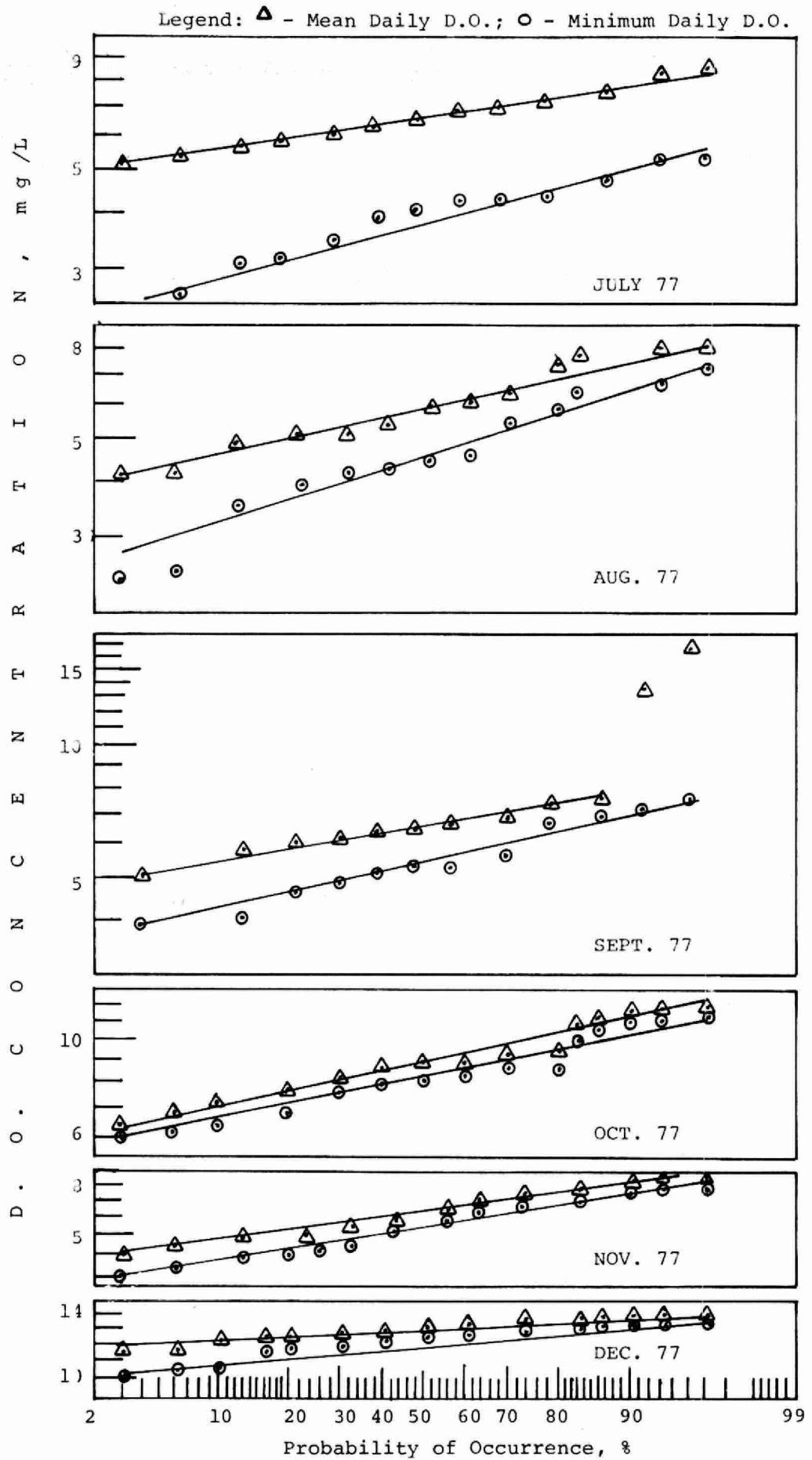


FIGURE 15 - CON'T.

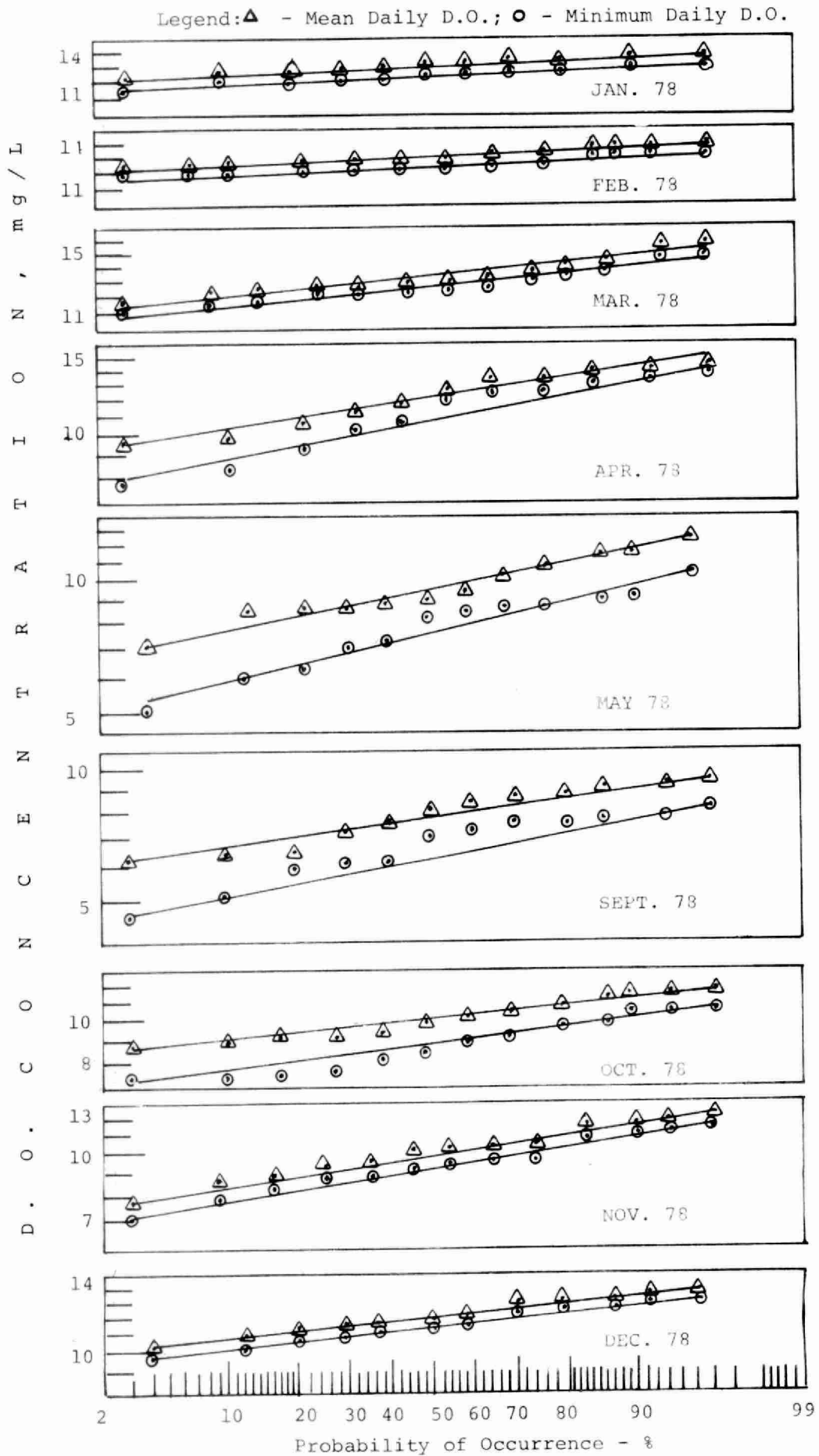


FIGURE 15 - CON'T.

#### 4.8 GRAND RIVER AT GLEN MORRIS - STATION E4

Station E4 is located at the downstream edge of the central Megalopolis area of the river basin. Probability distribution plots of mean and minimum DO levels for the period May 1976 - December 1978 are presented in Figure 16. There were no occurrences of minimum daily DO less than 4.0 mg/L in May of 1975, 1976 and 1978; however, there were several occurrences of minimum daily DO less than 4.0 mg/L in June, July and August of 1976 and 1977. DO levels of between 4.0 and 5.0 mg/L are common during this summer period.

GLEN MORRIS 1975

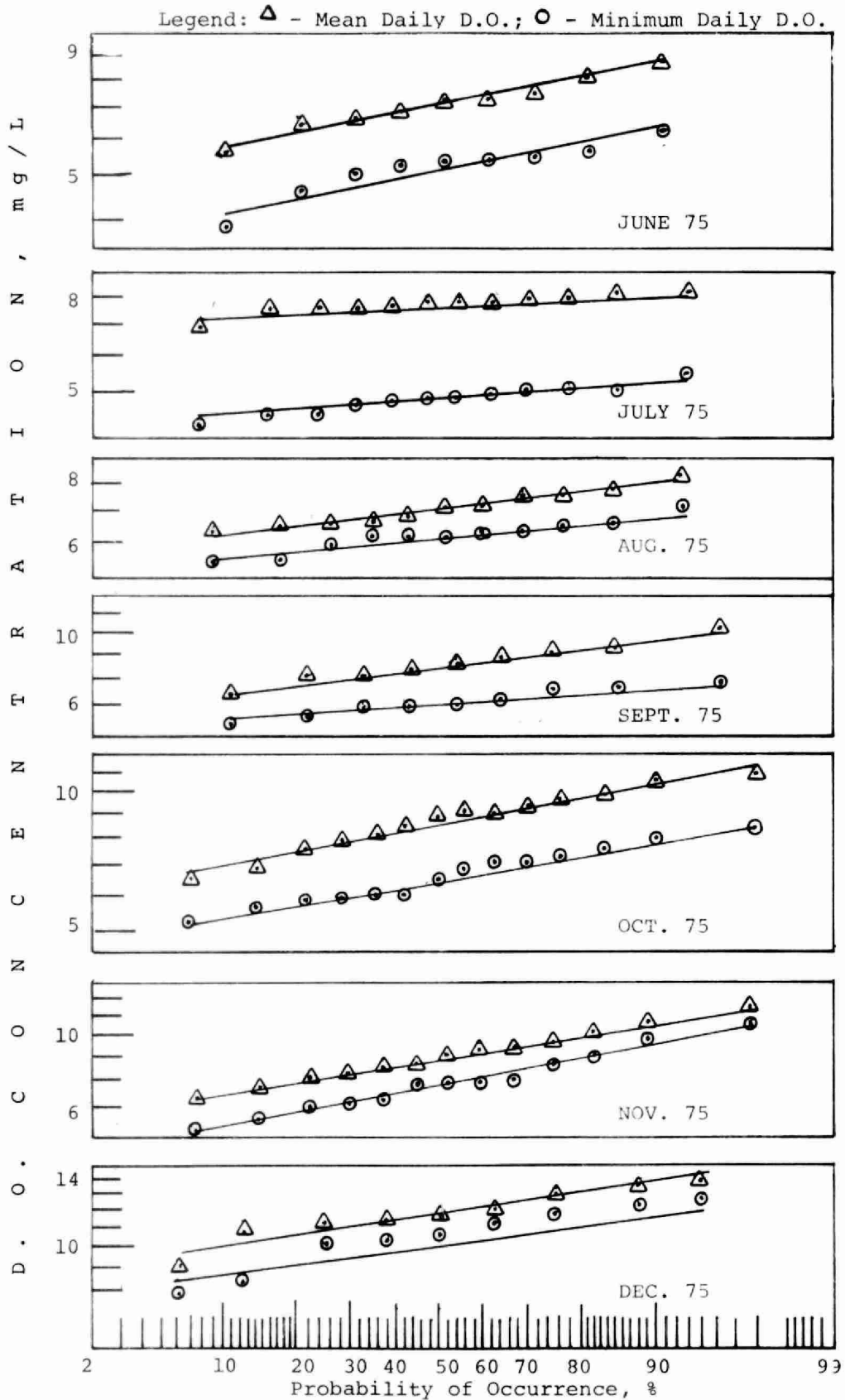


FIGURE 16 - PROBABILITY DISTRIBUTION OF D.O. LEVELS AT STATION E4 - GLEN MORRIS

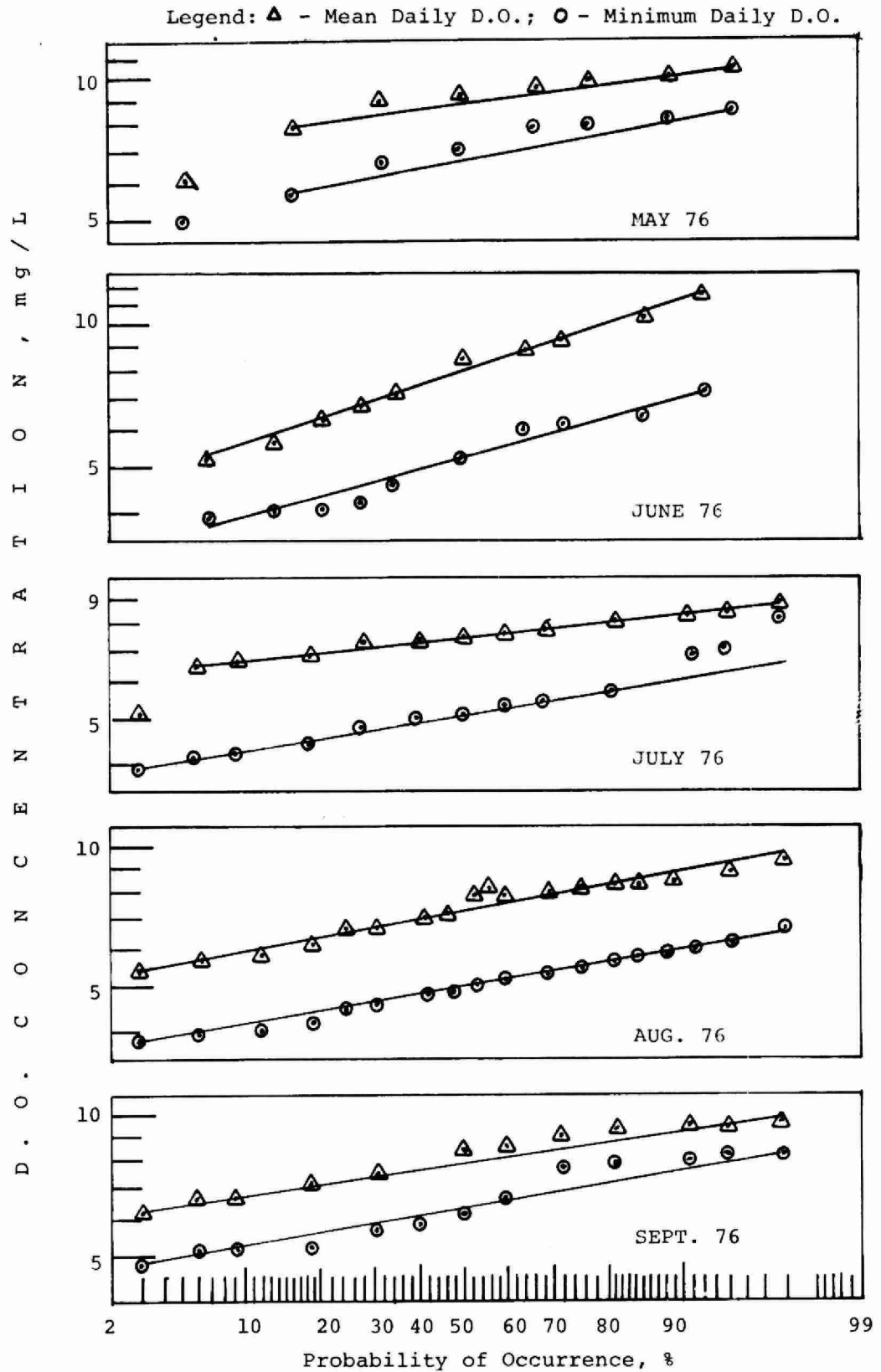


FIGURE 16 - CON'T.

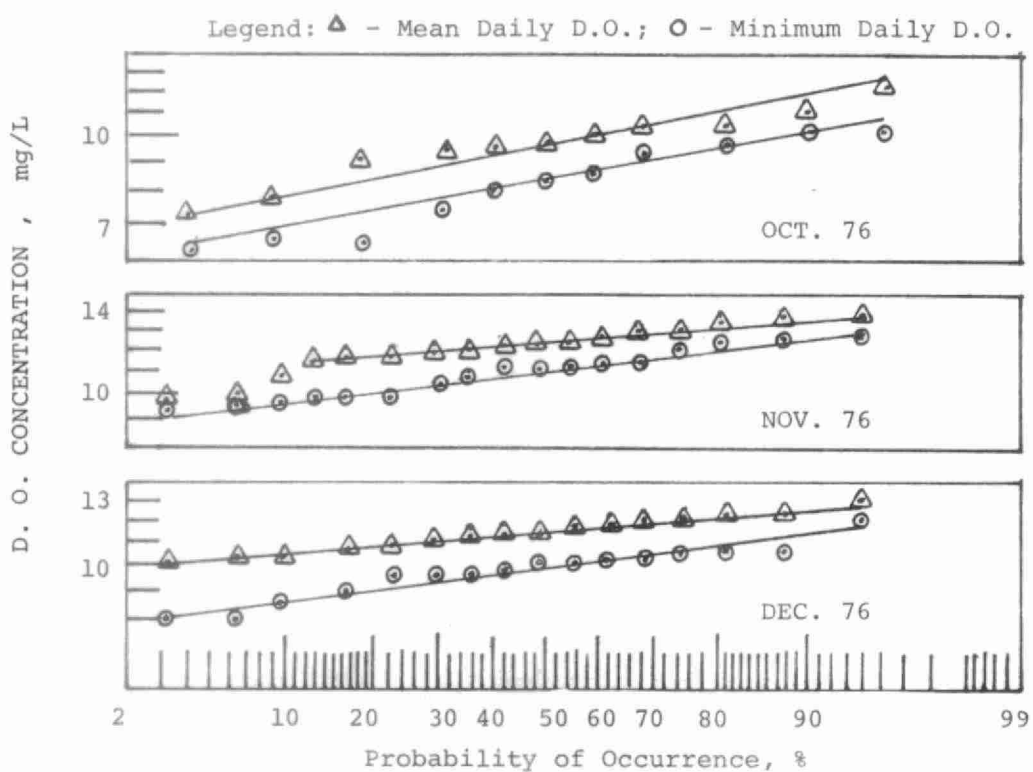


FIGURE 16 - CON'T.

GLEN MORRIS 1977

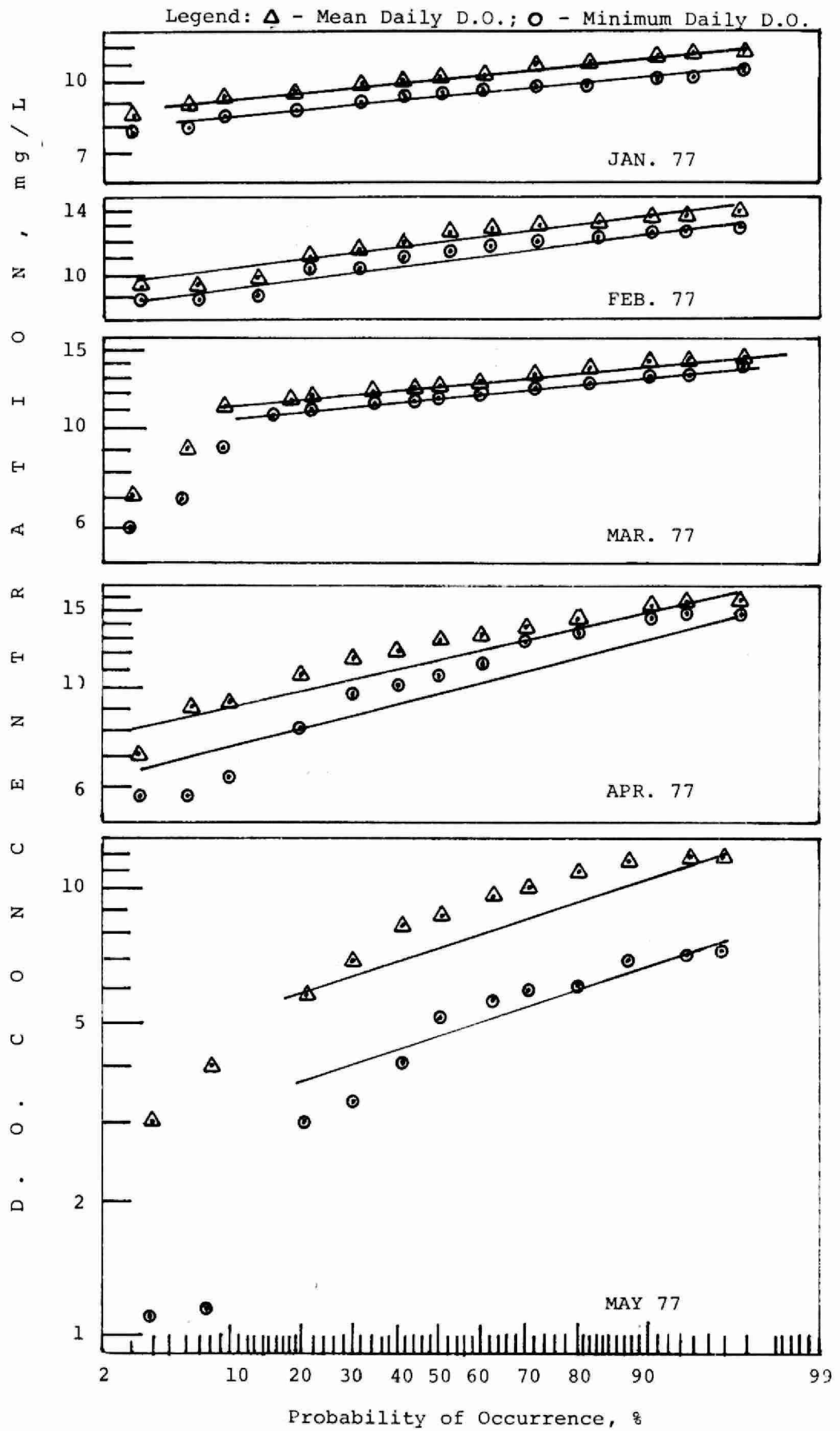


FIGURE 16 - CON'T.

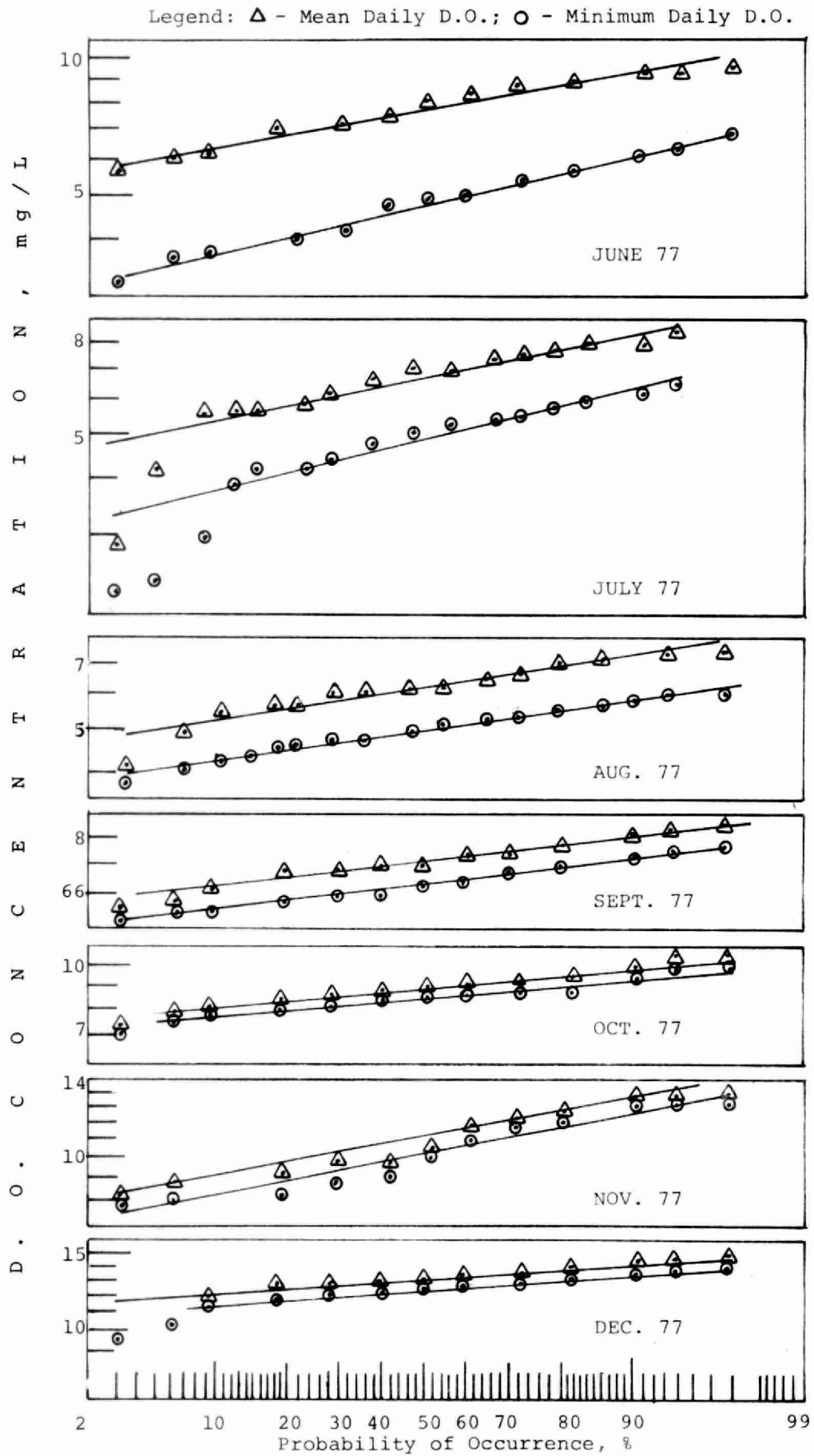


FIGURE 16 - CON'T.

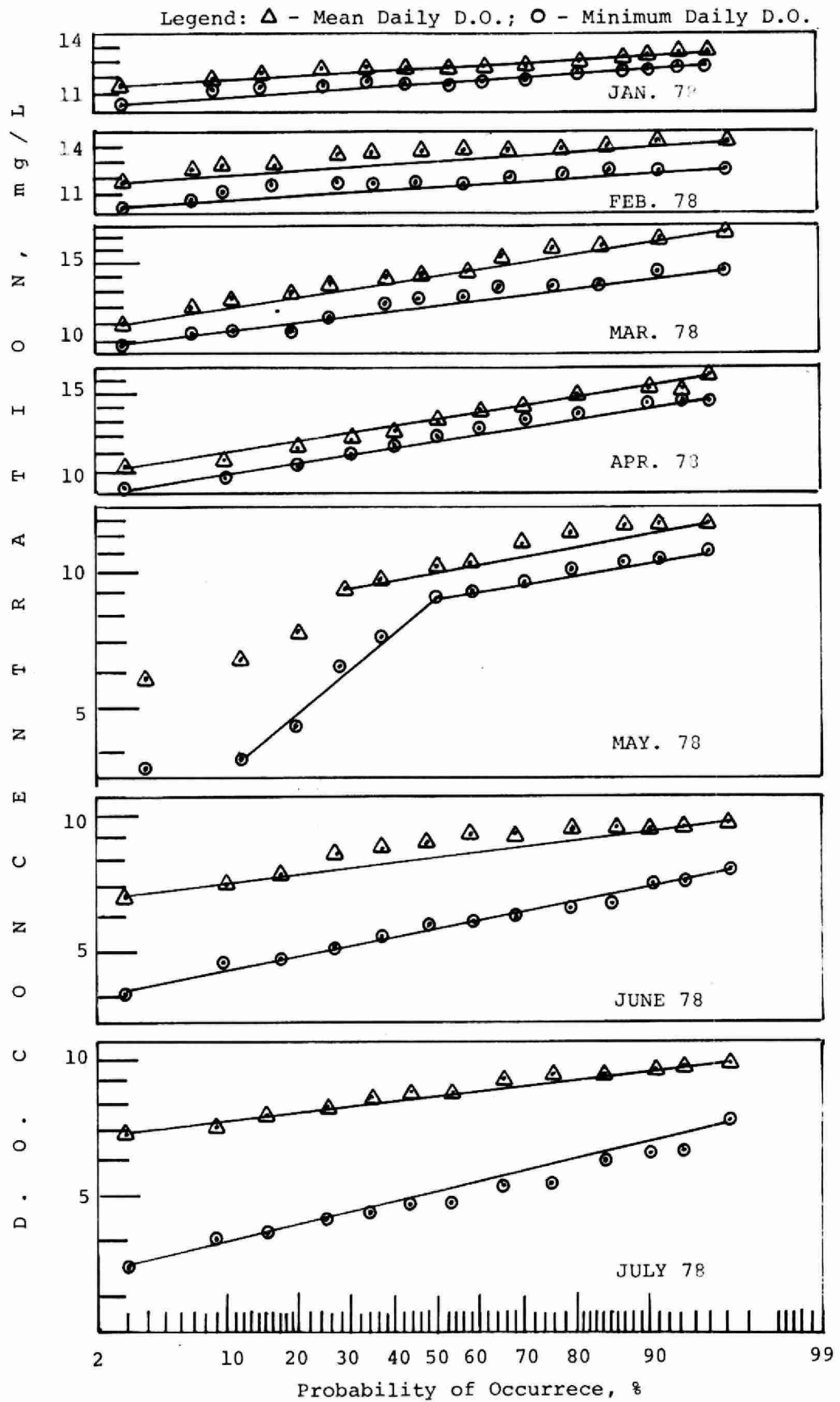


FIGURE 16 - CON'T.

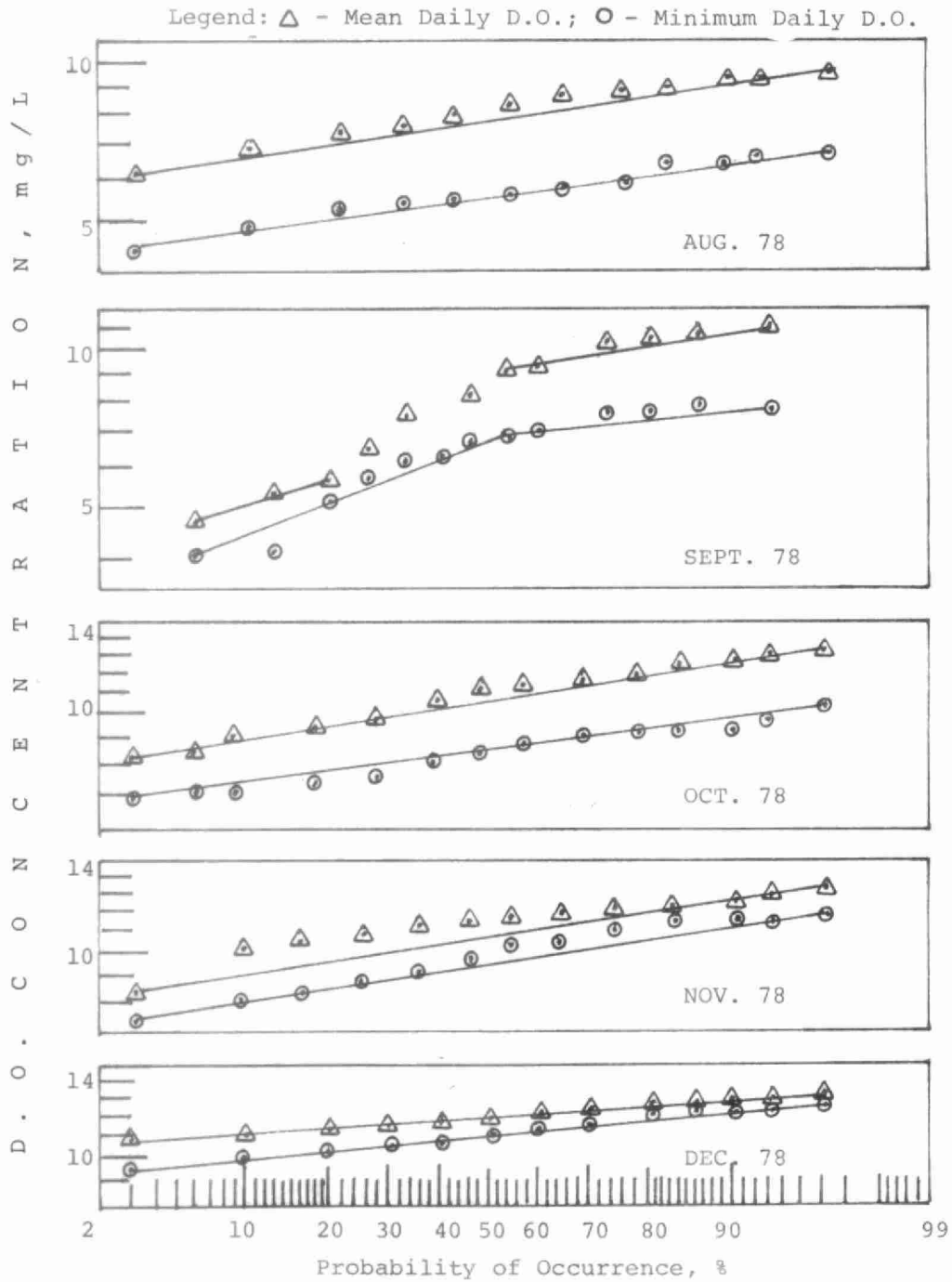


FIGURE 16 CON'T.

#### 4.9 PROBABILITY OF OCCURRENCE OF DAILY MINIMUM DO LEVELS

The DO probability plots shown in figures 10 to 16 indicate that the minimum daily DO levels were below 5 mg/L during the months of June and July at several stations. From these probability plots, station summary plots were derived; these plots, presented in Figure 17, show the percentages of days in each month during which the minimum DO levels did not exceed 4 mg/L, and 5 mg/L, at each station.

In the main branch of the Grand River between Bridgeport and the confluence, the minimum daily DO levels were occasionally lower than 4 mg/L during the months of May, June and July, whereas the DO levels were lower than 5 mg/L on up to 80% of the days during May-September. The DO levels required for the protection of warm water biota are only marginally being met during the months of May-September.

In the Speed River between Guelph and the confluence, the minimum DO levels are lower than 4 mg/L more frequently. At Glen Christie (Station N135), the minimum daily DO levels often approach zero, and are observed to be lower than 4 mg/L for up to 100% of the time. From the Glen Morris plot, it can be seen that the minimum daily DO levels were less than or equal to 5 mg/L on up to 60% of the days during May-September.

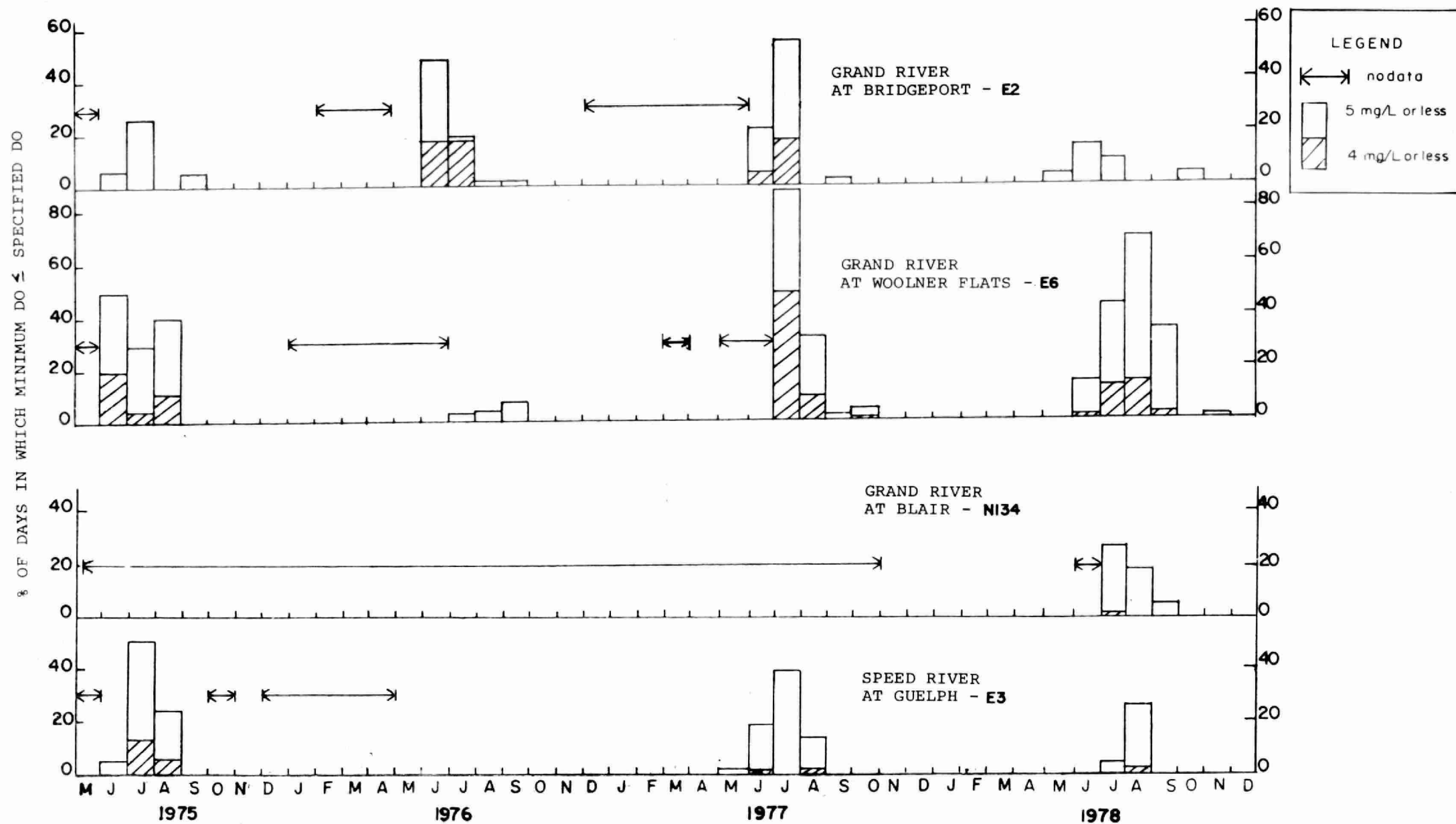
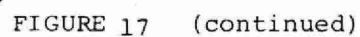


FIGURE 17 - % PROBABILITY OF OCCURRENCE OF SPECIFIED DAILY MINIMUM DO LEVELS AT VARIOUS STATIONS ON THE GRAND R. AND SPEED R 1975 - 1978



#### 4.10 VIOLATION ANALYSIS

Two types of violation analysis were carried out in order to interpret the results according to the traditional, as well as the present provincial DO criteria. Brief descriptions of the violation analysis procedures are presented. A comparison of the results of these two types of violation analysis is dealt with in subsection 4.10.3.

##### 4.10.1 Violation of Traditional DO Criteria

Formerly, the dissolved oxygen criteria were stated in terms of minimum concentrations of DO, irrespective of water temperature. The provincial DO criteria for warm water biota were stated as follows:

The dissolved oxygen (DO) concentration should be above 5 mg/L at all times, except that in certain situations concentrations may range between 5 and 4 mg/L for short intervals within any 24-hour period provided that water quality is favourable in all other respects. (8)

In order to interpret the DO records using these criteria, daily violation summaries of DO concentrations were obtained by using the computer program VIOLAT. This program prints out a daily summary of the number of hours during which the DO level was at or below a specified concentration level, viz: 1, 2, ... 9, and 10 mg/L or greater. The same tabulation is also shown as a percentage of time during which the DO levels were at or below the specified concentration levels. A typical output of the VIOLAT program is shown in Table 5.

NO. OF HOURS ON (MG/L) IS LESS THAN OR EQUAL TO STATED VALUE

PER CENT TIME DURING DAY IN (MG/L) IS  
LESS THAN OR EQUAL TO STATED VALUE

(4) - STATION -

[illegible]

#### 4.10.2 Violation of Present Provincial DO Criteria

The present provincial water quality objectives are stated as a function of temperature and are specified for two types of biota: warm water biota and cold water biota. It was decided to apply the objectives for the warm water biota in this analysis. The DO criteria for warm water biota are as follows:

At no time should dissolved oxygen concentrations be less than the values specified below:

Temperature, °C		0	5	10	15	20	25
Dissolved Oxygen Concentration	% saturation	47	47	47	47	47	48
	mg/L	7	6	5	5	4	4

In order to obtain DO violation summaries as per these criteria, a computer program VIONEW was developed. This program prints out the percentage time of violation of the DO levels for the above range of temperatures for each day, as well as the total time of violation during that day. A typical output of the VIONEW program is presented in Table 6. In this analysis it is assumed that the precise criterion is the percent saturation value and not the concentration value (also shown in the objectives), since the latter is an approximation of the former.

The tabulated violation summaries for the period May 1975 - December 1978, obtained from the VIOLAT and VIONEW programs, are on file and are available on request.

## GRAND RIVER AT GLEN MORRIS

## NEW VIOLATION ANALYSIS

## COLD WATER CRITERIA

PERCENT OF TIME DURING DAY DO (PERCENT)  
VIOLATES OBJECTIVES AT STATED TEMPERATURE

YR DAY	0	5	10	15	20	25	TOTAL
78 143				0.0			0.0
78 144				0.0	0.0		0.0
78 145				0.0	0.0		0.0
78 146				0.0	12.5		12.5
78 147					29.2	0.0	29.2
78 148					8.3	0.0	8.3
78 149					45.8	0.0	45.8
78 150					25.0	0.0	25.0
78 151				4.2	8.3	0.0	12.5
78 152				16.7	0.0		16.7
78 153				0.0	0.0		0.0
78 154				12.5	0.0		12.5
78 155		0.0	0.0				0.0
78 156		0.0	0.0	0.0			0.0
78 157		0.0	0.0	0.0			0.0
78 158				0.0			0.0
78 159				0.0			0.0
78 160				0.0	0.0		0.0

## WARM WATER CRITERIA

PERCENT OF TIME DURING DAY DO (PERCENT)  
VIOLATES OBJECTIVES AT STATED TEMPERATURE

YR DAY	0	5	10	15	20	25	TOTAL	NO. DATA PTS
78 143				0.0			0.0	15.
78 144				0.0	0.0		0.0	24.
78 145				0.0	0.0		0.0	24.
78 146				0.0	8.3		8.3	24.
78 147					16.7	0.0	16.7	24.
78 148					0.0	0.0	0.0	24.
78 149					12.5	0.0	12.5	24.
78 150					8.3	0.0	8.3	24.
78 151				0.0	0.0	0.0	0.0	24.
78 152				0.0	0.0		0.0	24.
78 153				0.0	0.0		0.0	24.
78 154				0.0	0.0		0.0	24.
78 155			0.0	0.0			0.0	24.
78 156			0.0	0.0	0.0		0.0	24.
78 157			0.0	0.0	0.0		0.0	24.
78 158				0.0			0.0	12.
78 159				0.0			0.0	12.
78 160				0.0	0.0		0.0	24.

\*\*\*\*NOTES TO ABOVE TABLE\*\*\*\*

1- A BLANK VALUE INDICATES THAT THE DATA WERE OUTSIDE OF THIS TEMPERATURE RANGE

2- A VALUE OF 0.0 INDICATES THAT THERE WERE DATA IN THIS TEMPERATURE RANGE BUT NO DO VIOLATIONS OCCURRED

TABLE 6: SAMPLE OUTPUT OF VIONEW PROGRAM

#### 4.10.3 Comparison of Violation Analysis Results

In order to compare the violations of the foregoing types of DO criteria, average percentage times of DO violations in each month were calculated as follows:

- (1) From the VIOLAT program output, the daily average percentage of data violating the 4 mg/L criterion was computed for each station.
- (2) Similarly, the daily average percentage of data violating the 5 mg/L criterion was computed for each station.
- (3) The daily average percent of data violating the present DO objectives for warm water biota in each month was computed from the VIONEW program output.

These results are compared in Figure 18. In some months, the former DO criteria would be in violation, whereas the new criteria are not being violated. Generally, violation of the new criteria is more frequent than violation of the 4 mg/L level, but is less frequent than violation of the 5 mg/L level.

At all stations except the Speed River station at Glen Christie (N135), the percentages of violations of a 5 mg/L criterion would be higher in comparison to violations of the new provincial objectives. In addition, months occur where violations are in evidence for the former criterion of 5 mg/L, but not for the new objectives (e.g., summer 1978 at station E2-Bridgeport). However, at the Speed River NERA Station (N135), the percentages of violations of the new provincial objectives are higher than those of the former criteria; the months in which violations occur are almost the same in both cases.

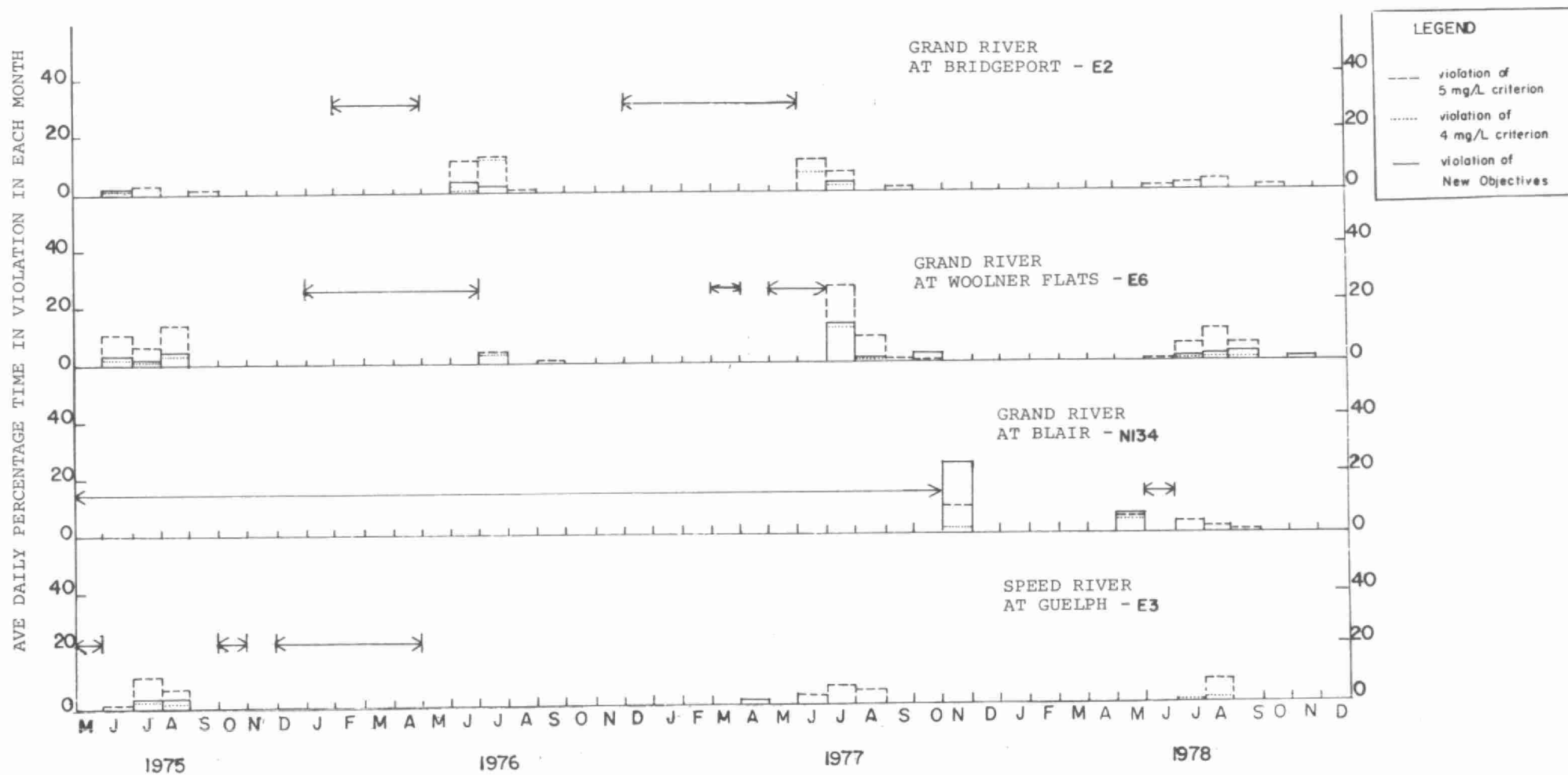


FIGURE 18 - AVERAGE TIME OF VIOLATION OF DO CRITERIA  
AT VARIOUS STATIONS IN THE GRAND R. AND  
SPEED RIVER DURING 1975-1978

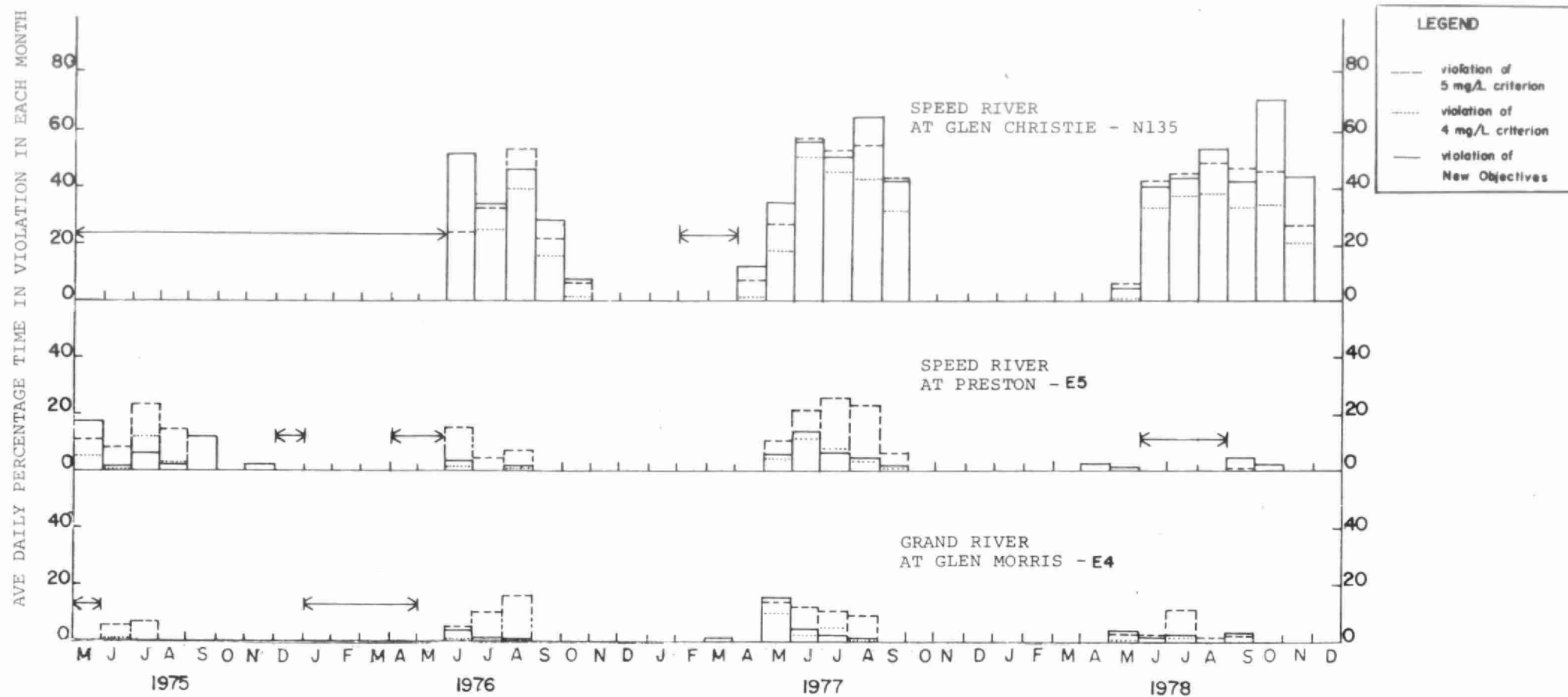


FIGURE 18 -(continued)

## 5. SUMMARY AND CONCLUSIONS

Technical Report No. 11 deals with the continuous monitoring of water quality at seven stations, operational since 1975, in the central megalopolis area of the Grand River basin. At five stations, DO and temperature are monitored continuously by EIL instrument systems; at two other locations, DO, temperature, conductivity, pH and oxidation-reduction potential are recorded at half hourly intervals by NERA instrument systems. The results of the statistical and probabilistic analyses of the DO data collected at the seven stations during the period 1975-78, as presented, appear suitable for calibration and verification of the continuous simulation water quality model, which is being developed for application to the Grand River system.

An analysis of the magnitude and duration of violations of provincial warm water DO criteria by recorded DO levels has been carried out. The violation analysis is based on former provincial DO criteria (in which minimum concentrations are specified), as well as the present provincial water quality objectives wherein the DO requirements for aquatic biota are specified as a function of temperature. The DO data record was evaluated in terms of these two types of criteria and a comparison made.

The following conclusions summarize the results of the analyses presented in the report:

1. The DO levels in the Grand River at Bridgeport (Station E2) were generally above 5 mg/L with some exceptions during the months of June and July when the minimum DO levels were below 4 mg/L on up to 20% of the days.
2. At Woolner Flats in the Grand River (Station E6), the DO concentrations were high relative to provincial objectives, with some exceptions during July and August 1977, and June-September 1978.

3. In the Grand River at Blair (Station N134), the DO levels were generally higher than 4 mg/L during most of the recording period.
4. With the exception of July 1975, the DO levels in the Speed River at Guelph (Station E3) were greater than 4 mg/L; however, for some summer months, the daily minimum DO concentrations were lower than 5 mg/L on over 30% of the days. This station had the most acceptable DO conditions, relative to provincial objectives, of any of the stations with a four year data record.
5. In the Speed River at Glen Christie (Station N135), the minimum DO levels were frequently lower than 4 mg/L during the period May-November. In 1978, the daily minimum DO values were below 5 mg/L for the period May to October, and in July and August the minimum values were below 4 mg/L. This station had the most unacceptable DO conditions, relative to present provincial objectives, of any of the continuous DO monitoring stations.
6. At the mouth of the Speed River, at Preston (Station E5), the daily minimum DO levels were lower than 4 mg/L on up to 60% of the days during some months.
7. On the Grand River at Glen Morris (Station E4), the daily minimum DO concentrations were less than 4 mg/L during May-July on up to 30% of the days, and less than 5 mg/L during the same months on up to 60% of the days.
8. A comparison of the DO violations of former provincial criteria against present provincial DO objectives for warm water biota indicates that more violations of the fixed 5 mg/L criterion occur than violations of the new objectives. This is true for all stations except station N135 on the Speed River at Glen Christie, where the opposite is true. Most stations therefore show months during which violations occur of the former criterion, but not the present objectives.

## REFERENCES

1. BIRCH, K.N., Palmer, M.D., Cullen, D.H., and Masuda, A.,  
"Automated Water Quality Monitoring in Canada -  
Present Practice and Trends for the Future", presented  
at The Instruments and Control Systems for the Water  
Industry - A Water Research Centre Conference,  
September 15-17, 1975, pp: 1-20.
2. DAVIES, A.W., "The Application of Continuous Water Quality  
Monitoring to River Management in the Future", - Water  
Pollution Control (U.K.), Vol. 71, 1972, pp: 523-532.
3. ELECTRONIC INSTRUMENTS LIMITED, "Model 15A Dissolved Oxygen  
Meter with Model A15A Biological Oxygen Electrode  
Operating Instructions", - Chertsey, Surrey, England,  
August, 1973.
4. NERA, Inc., "NERA Environmental Monitor - Operation of the  
Model 4", - Bedford, Massachusetts, U.S.A., 1974.
5. GOSEN, D., "Operations Report, 1975", - Hydrology and  
Monitoring Section, Water Resources Branch, Ontario  
Ministry of the Environment, Toronto, Ontario, Canada  
(Internal Report).
6. FRANK, D.C., "Grand River Studies, Continuous Monitors -  
Operations Report, 1976", - Hydrology and Monitoring  
Section, Water Resources Branch, Ontario Ministry of  
the Environment, Toronto, Ontario, Canada (Internal  
Report).
7. ONTARIO MINISTRY OF THE ENVIRONMENT, "Automated Dissolved  
Oxygen Computations", - Hydrology and Monitoring  
Section, Water Resources Branch, Toronto, Ontario,  
Canada, 1976, (Internal Report).

8. ONTARIO MINISTRY OF THE ENVIRONMENT, "Guidelines and Criteria for Water Quality Management in Ontario", - Toronto, Ontario, Canada.
9. ONTARIO MINISTRY OF THE ENVIRONMENT, "Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment", - Toronto, Ontario, Canada, November 1978.
10. WILLSON, K., "Computer Program Documentation for River Systems NERA Programs", - Water Modelling Section, Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario, Canada, January, 1980 (Internal Report).

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